ASTRONOMY

April 1980
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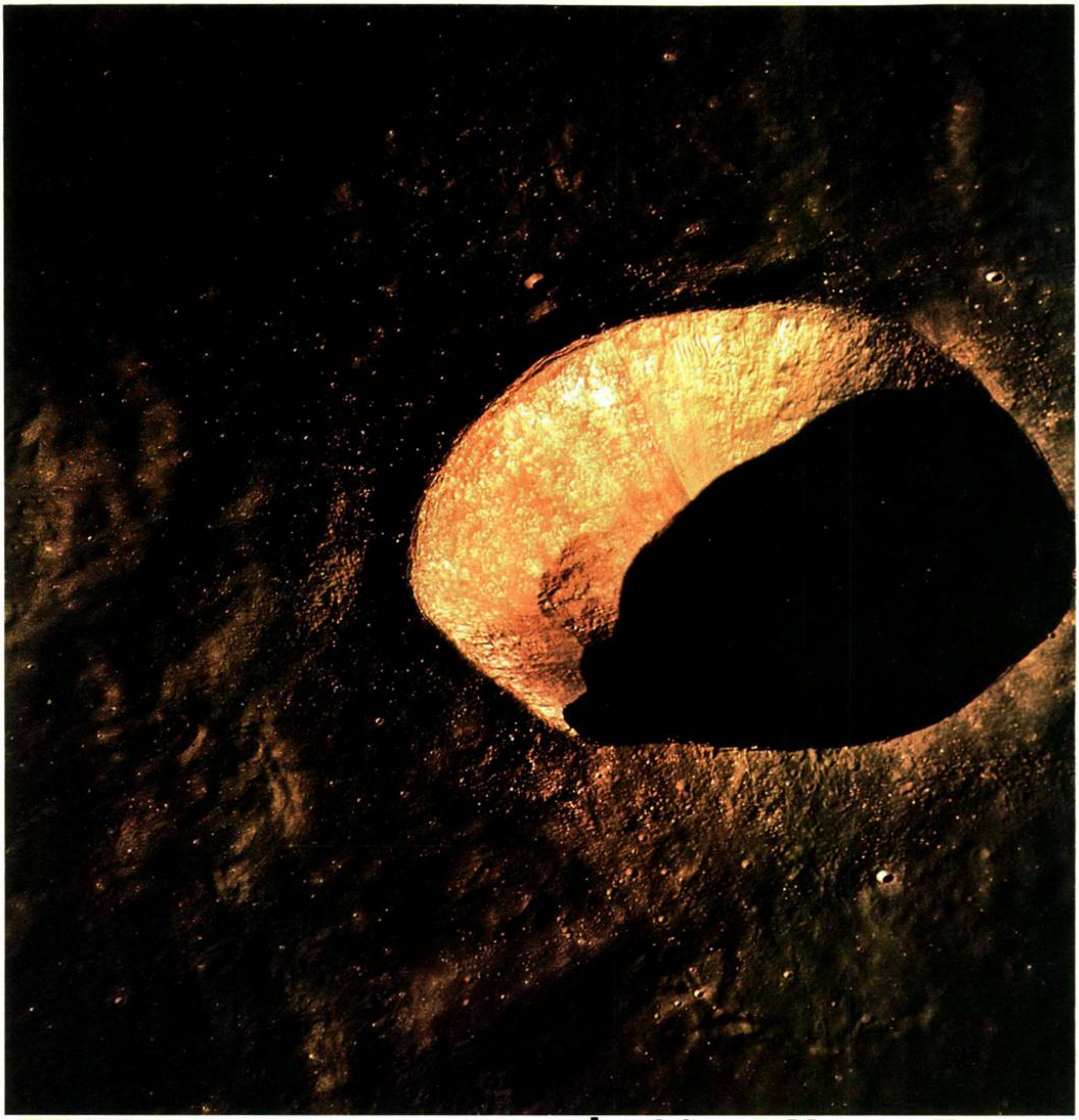
Return to the Moon

What Accessories Do You Really Need?

Astronomy on the Sidewalk



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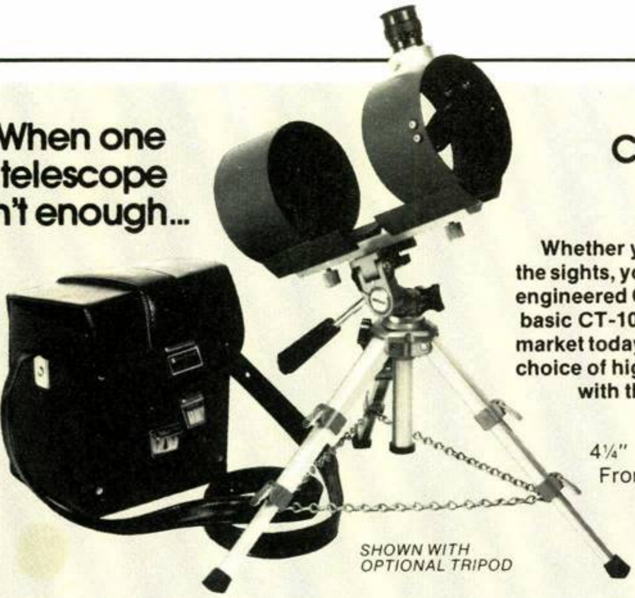

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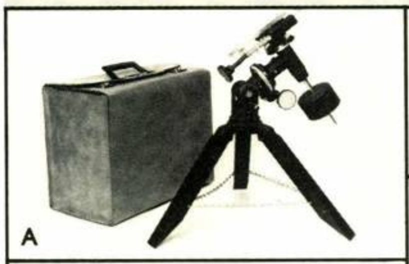

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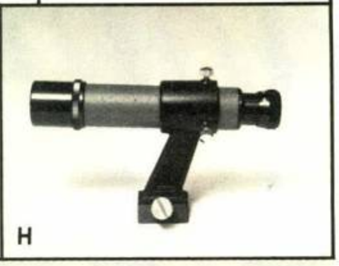

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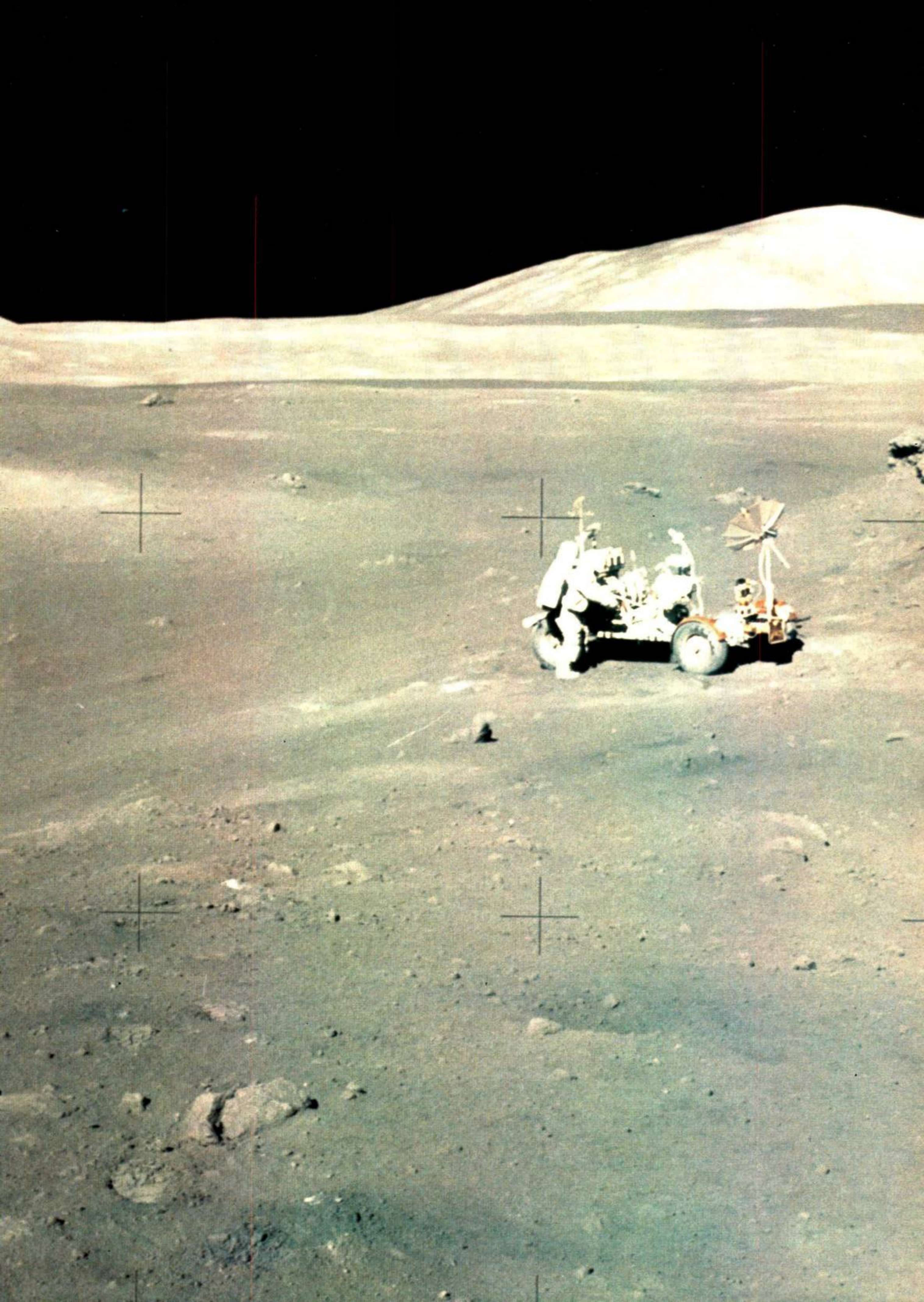

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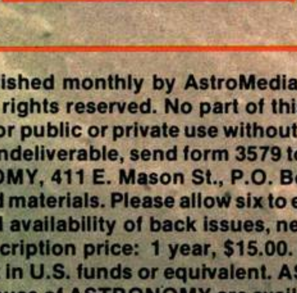

Cover: During the final reconnaissance flight before astronauts landed and began the exploration of the Moon, Apollo 10 astronauts photographed the crater Schmidt, located at the western edge of Mare Tranquillitatis. Schmidt is 7 miles in diameter, readily visible in amateur-size telescopes, just south of Ritter and west of Sabine. This page: Some three years later, on the final Apollo flight, at the greatest distance ever achieved from the lunar descent module, an astronaut photographed the lunar rover beside the crater Nansen. This month, ASTRONOMY explores the prospects for returning to the Moon. NASA photographs courtesy of Lunar and Planetary Institute.

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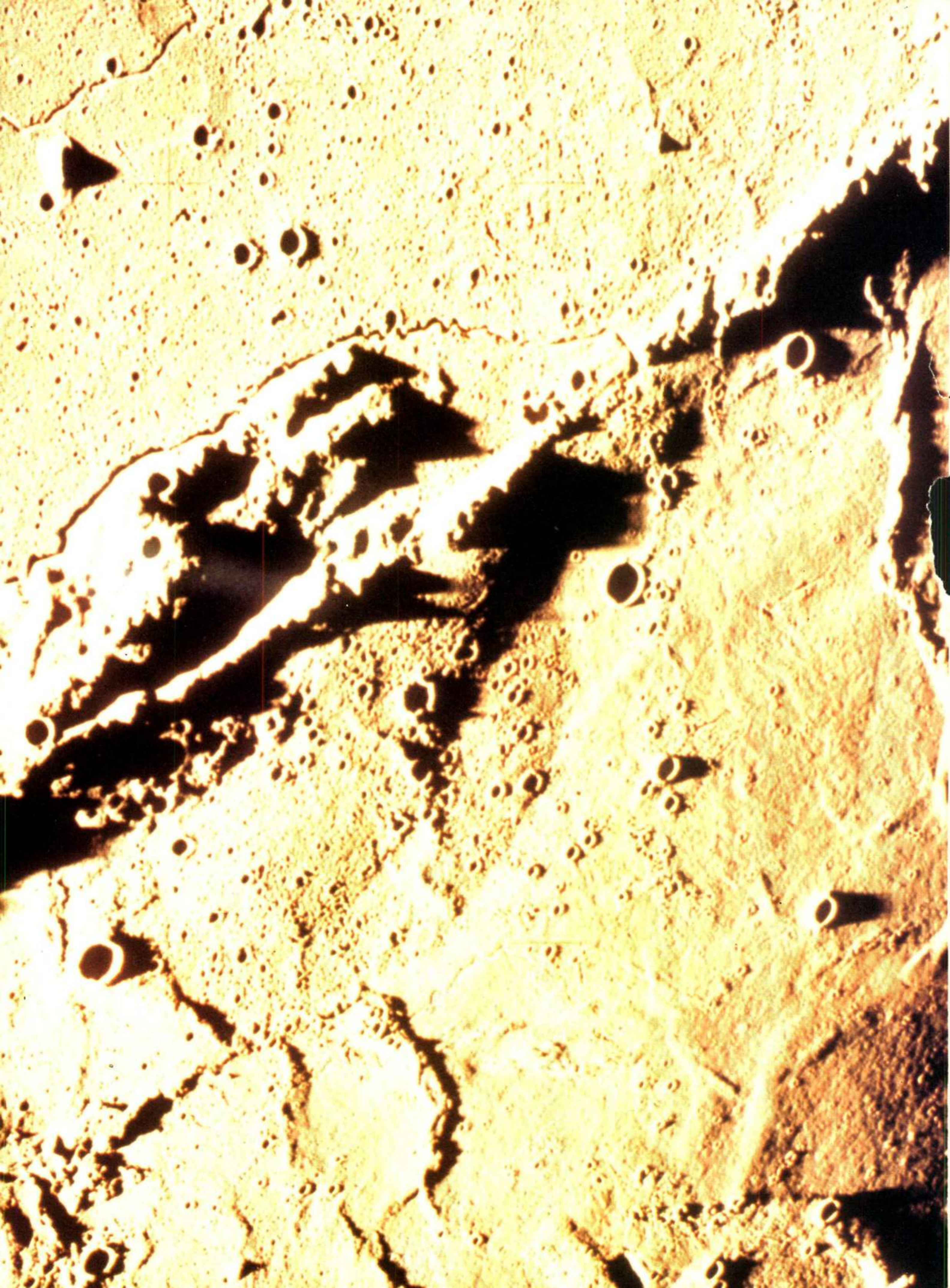

Return to the MooN

by Michael A.G. Michaud and Leonard W. David

Eight years ago this December, astronaut Eugene Cernan lifted his moon-soiled boot to the ladder of a lunar module, ending the last direct human contact with the Moon. When Apollo 17's crew splashed down in the Pacific three days later, the Earth-Moon transport link was broken, and Luna regained its title of a dead world.

Twelve astronauts had walked on the lunar surface between 1969 and 1972, for a total stay time of a little under one week. These temporary visitors left artifacts of our most advanced technology, including lunar go-carts called Rovers and Apollo Lunar Science Experiments (ALSEPs) — equipment designed to radio reports of moonquakes and meteorite impacts back to Earth. Other relics of humankind's presence dot the near side of the Moon, from the remains of crashed U.S. Ranger spacecraft and spindly-legged Surveyors to the Soviet Luniks and Lunokhods. And there are those monuments to technological excellence: the six pedestals that supported the lunar modules and their human cargo.

Apollo died a budgetary death, before our reconnaissance was complete. Apollos 18, 19, and 20 would have used a growing confidence in man and machine to reach for such forbidding locations as the inside of lunar craters — bright-rayed Tycho and giant Copernicus, both punctuated by central peaks jutting thousands of feet into the empty lunar sky. We left nearly all of the Moon unexplored; the lunar highlands were hardly touched, the polar regions remain unseen, and no one has yet set foot on the far side.

Our brief and scattered surveys have raised as many questions as they answered. Does the Moon have a molten core? Why does the far side have a thicker crust than the near side? What are the origins of the Moon's hot spots — are they potential gas wells leading down to a still active interior? Could the Moon have hidden ice, frozen away near its poles, or underground, out of reach of the Sun's thawing rays?

NASA photo

We cannot know until we return.

The New Moon

Apollo is now history — dismantled, filed away in our collective memory. But it made us see the Moon in a different way. That distant ball of rock is no longer just a cold light in the night sky, or a poetic abstraction; it is now familiar. Through television, we became armchair astronauts, watching space-suited figures shuffle and bounce across the lunar surface, placing experiments, chipping rocks, taking pictures like tourists, drilling holes, even tripping and falling down. We saw fellow humans drive their Rovers across lunar terrain, tossing up dust like adventurers racing across an earthly desert.

We spoke of Apollo landing sites — the Sea of Tranquillity, the Ocean of Storms, Fra Mauro, Hadley-Apennine — as if they were exotic locales on another continent. We could picture ourselves walking on that new land, exploring its wilderness, skipping in its light gravity. We realized that the "Man in the Moon" could be ourselves.

Apollo also brought back something more tangible — 843 pounds of rocks. Examining them, scientists found the Moon was composed of the same materials as Earth, but in different proportions. Elements have concentrated differentially into specific areas of the Moon's surface, with the light-colored highlands rich in calcium and aluminum, while the dark maria ("seas") contain larger quantities of titanium, iron, and magnesium. Lunar surface rocks seem depleted of volatiles, the light elements such as hydrogen which would escape most easily from the Moon's weak gravity. However, the typical Apollo sample is rich in useful elements, containing (by weight) over 40% oxygen, more than 20% silicon, 12% aluminum, 6% titanium, 4% iron, and 3% magnesium.

For the first time, we can begin to think seriously of the Moon as a resource. We know it is a rich deposit of minerals, an economic treasure-trove just off the shore of an increasingly scarred and depleted Earth. Armed with this new knowledge, many scientists visualize active utilization of the Moon, an idea reaching far beyond scientific exploration. It is this potential economic use of the Moon that may bring about its permanent inhabitation, the creation of a second world for humankind, more than justifying the cost of Apollo.

The battered highlands of the lunar far side may conceal valuable minerals to feed lunar industries. Seen and photographed only from orbit, these hills will be visited again, the next time on foot, when we return for further explorations. NASA photograph courtesy of Lunar and Planetary Institute.

Lunar Prospecting

Our assay of the lunar rocks will hardly spark a gold rush of prospectors in space helmets. Future Moon surveying will begin with new generations of space robots, such as a Polar Lunar Orbiter (POLO) — an unmanned probe to circle the Moon, studying its surface from pole to pole with sophisticated remote sensors. Since the Apollo spacecraft were compelled — by trajectory and fuel constraints — to orbit relatively close to the lunar equator, the POLO mission would give us, at last, a detailed geophysical and geochemical map of the entire lunar globe.

POLO would point the way for more intensive investigations of the surface, possibly with unmanned sample return vehicles (like the Russian Lunokhod) built to send back chunks of lunar rock and soil to Earth. We could send a sophisticated miniature chemical laboratory, like the Viking lander which analyzed martian soil, to digest lunar minerals and signal back its findings. Or we could send a roving vehicle to wander over the most interesting areas, sampling the surface at many points. These robot prospectors may show where the richest lodes are likely to be found, and prepare the way for our return.

Human Explorers: the Second Wave

There will be no more quick trips on giant rockets, with astronauts hurriedly collecting a few samples of rock. This time, the cargo-carrying Space Shuttle will allow us to assemble modest and efficient but unstreamlined vehicles in low Earth orbit. Lunar-capable "space tugs" will push canisters of humans and tools into lunar orbit, perhaps to join a space station there. After landing on the lunar surface in their descent craft, astrogeologists will resume the exploration of the Moon in a comprehensive, systematic way.

These explorers will be the first humans to stay on the Moon for more than a few days. They will need a

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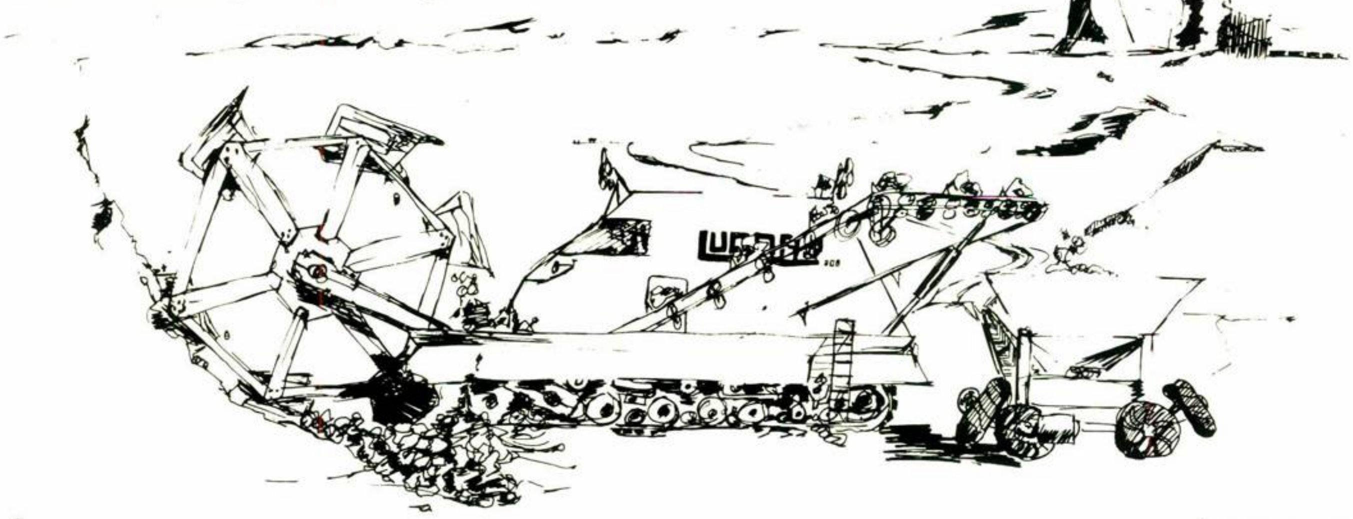


place to live, the first true lunar habitat. During the Apollo program, NASA was developing a manned Lunar Exploration System Apollo (LESA). In this concept, a shelter would support from three to six people for up to six months. The new lunar teams instead might begin their residence in a group of modules landed close together, clustering tightly for survival like a research station in the Antarctic.

This exploration camp would be no glamorous "Moon Base Alpha"! It would be more like several quonset huts with airlocks. From them, lunar researchers would set out in their wheeled or tracked vehicles across the dusty terrain. The LESA studies outlined a need for rovers with a range of 200 to 300 miles, capable of remaining away from the main base for 9 to 12 days; long-range mobile laboratories may be limited only by the coming of the two-week lunar night and its bitterly cold temperatures.

A lunar geologist, climbing a ridge to scan the startingly near horizon, might wonder if humans would ever really live on the Moon; there would be no green vegetation, no clouds moving on the breeze, no voices but those in his radio headset. Yet for decades nations have maintained scientific stations in the Earth's polar regions, where icy winds howl, skies are whited out, and temperatures drop to 120° F below zero. Some of these bases have become permanent settlements, including one at the South Pole itself. Already, the first child has been born in Antarctica. And long-term residents have discovered beauty in that seemingly forbidding White Continent.

Moon Base

As recently as 1976, a special million dollar NASA study titled *Outlook for Space* considered a base on the Moon a "keystone for the development of space in the vicinity of Earth." While they explore for minerals, prospectors could help select potential locations for a permanent moon base — a headquarters for future activity on Luna. This second generation lunar habitat might grow from a cluster of survival modules left by exploration teams, either incorporated into a larger design or left separate for peripheral functions, like storage sheds on a farm.

Before the cancellation of Apollo, NASA and its contractors developed several Moon Base proposals. The studies chose a base built on the surface and then covered with lunar dirt to shield the habitat from extremes of temperature, solar flares and cosmic rays, and micrometeorites: a basic lunar "home away from home" to house as few as two people and as many as eighteen.

Alternative plans involved gouging wide trenches in the lunar surface and lowering into them cylindrical modules, connected to form a subdividable habitation, safely buried beneath the lunar desert. Solar energy collectors, launch and landing pads, observatories, and other base facilities would be on the surface.

Such a base might resemble Camp Century, a station built by U.S. Army engineers in the Greenland icecap during the 1950s. But living in a comfortable cave underground (while certainly safer) may have bad side effects. Psychological distress could impel residents at Moon Base to demand windows for viewing the lunar landscape or Earth. These needs could be all-important, dismissably trivial, or something in-between depending on the personalities involved. We don't yet know.

In visualizing lunar habitats, we transport to the Moon our earthly attitudes about living on the new frontier. When we see Luna only as a place to be explored and endured, Moon Base is a place of survival in a hostile environment, with antiseptic, military-style modules. But if we look at the Moon as a future home for humankind, Moon Base then is a city, spacious and bright and full of living things.

Architects John Dossey and Guillermo Trotti, thinking about livability as well as survival, have designed a lunar colony they call Counterpoint, to be situated in St. George Crater near Apollo 15's landing site at the foot of the lunar Apennine Mountains. Beginning with a basic crew of 15 to 20, the colony would grow to 200 people over 10 years. Counterpoint would be complete with its own soybean farms, civic center, library, and chapel, the latter on a tower high above the dust. (A model of the Counterpoint design is on display in the National Air and Space Museum in Washington, DC.)

Another interesting possibility is to establish Moon Base in the polar regions, where ice may survive in deep valleys or on permanently shaped slopes. Atop the "Mountains of Eternal Light," near the Moon's south pole, observatories would see half the sky continuously, and a sun-tracking mirror (called a heliostat) could collect solar energy for the base. On the other hand, a base near the lunar equator would permit incoming and outgoing vehicles to burn less energy on their trajectories to and from orbits around the Earth. Locating a base on a high peak (some lunar mountains rise to Himalayan heights) could convey the same advantage. But the safety of landing in flat terrain and the ease of ground movement outside mountainous areas may prove to outweigh all these ideas.

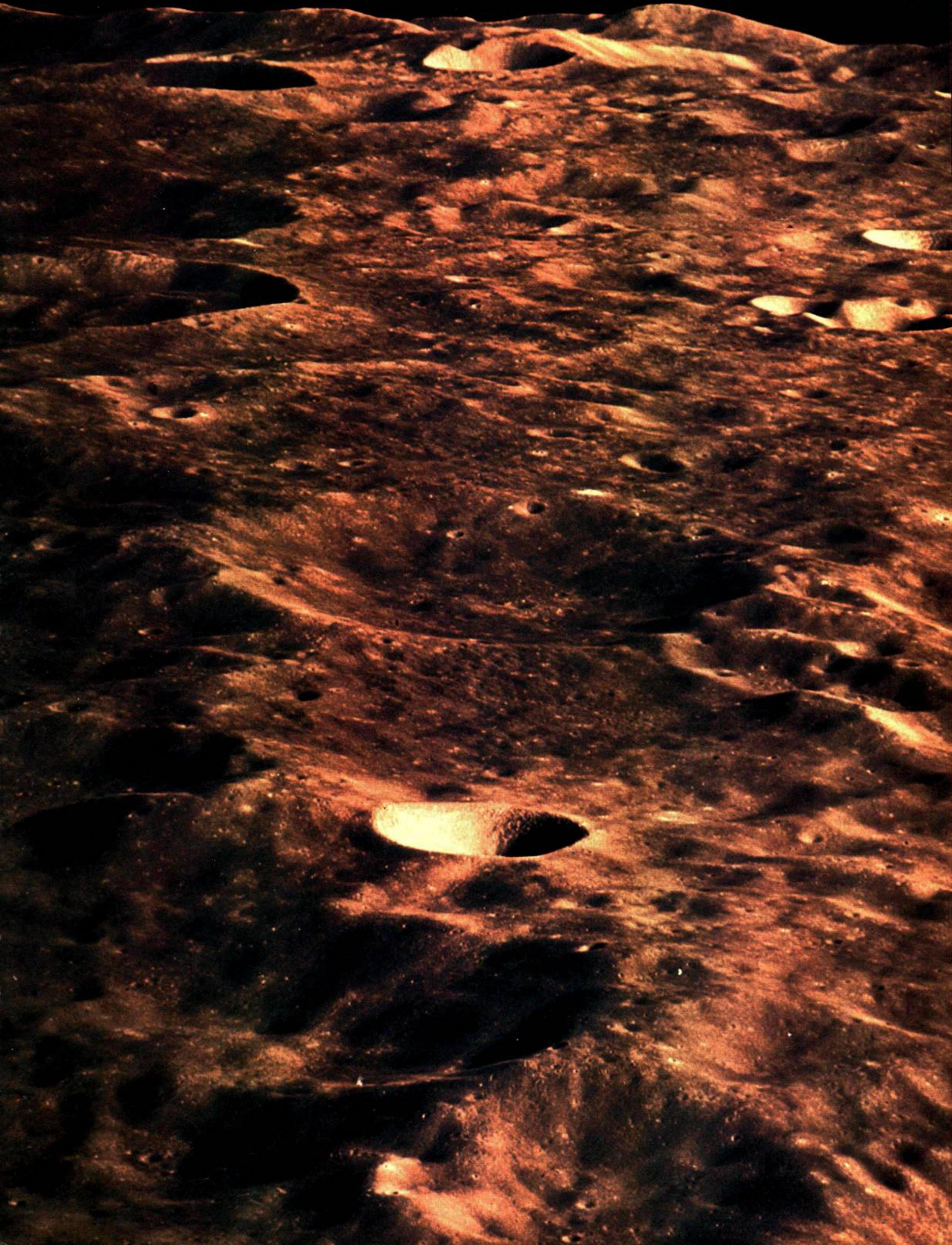
Dr. Paul Lowman, a geophysicist at the NASA Goddard Space Flight Center in Maryland who has studied Moon Base locations in detail, suggests putting it in or near the crater Grimaldi, near the Sea of Storms. "It is easy driving," he says, "to a geological paradise of younger formations, potential gas wells, and areas which may contain material from deep in the lunar interior."

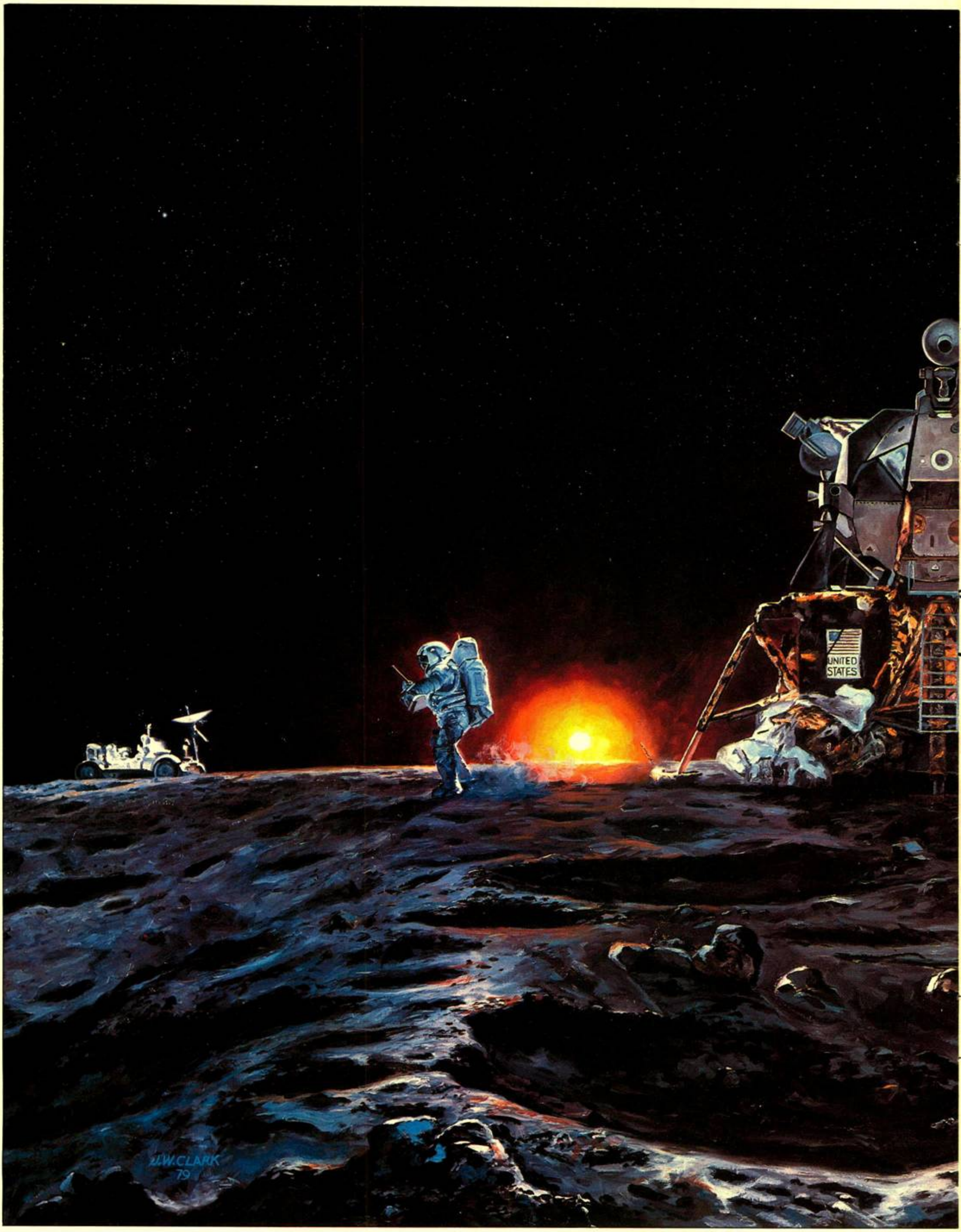
That location may be a geologist's dream, but miners would want the Moon Base atop the richest lodes of minerals or underground veins of water ice. Astronomers, however, need a clear field of vision and no radio interference. Communication with Earth would be easier from the Moon's near side, but relay satellites in lunar orbit could permit the base to be anywhere. Where the base (or bases) end up will likely be a compromise between economic, scientific, and human needs.

The Closed Ecology

The Moon is an unforgiving environment for life. With no atmosphere, it receives the full blast of the

The Moon's surface presents an incredibly difficult geological problem for those who wish to unravel its complex sequence of events. Here is typical highland terrain, nearly saturated with craters: the oldest are distorted and buried by generations of fresher impacts. NASA/LPI photograph.

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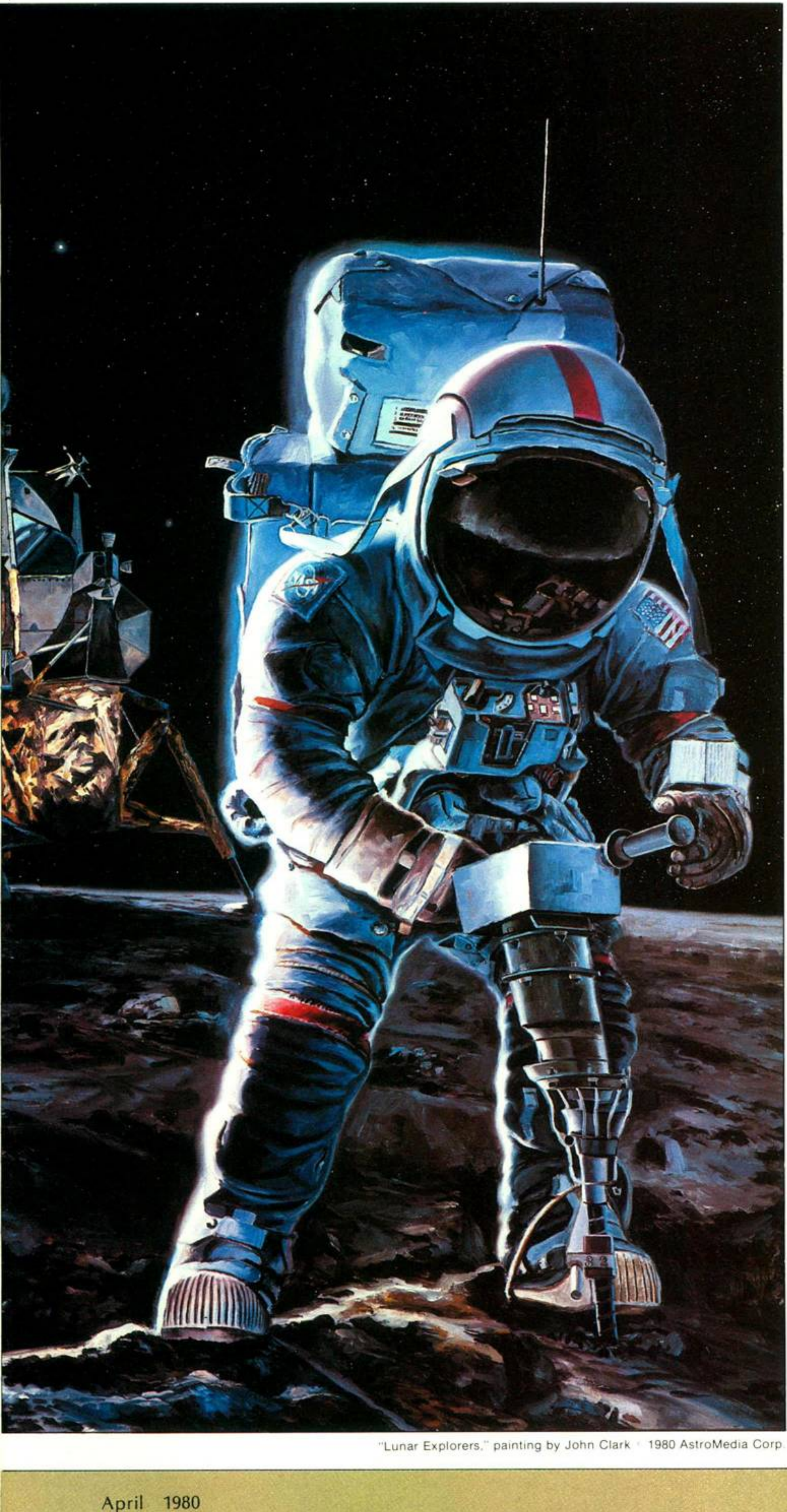
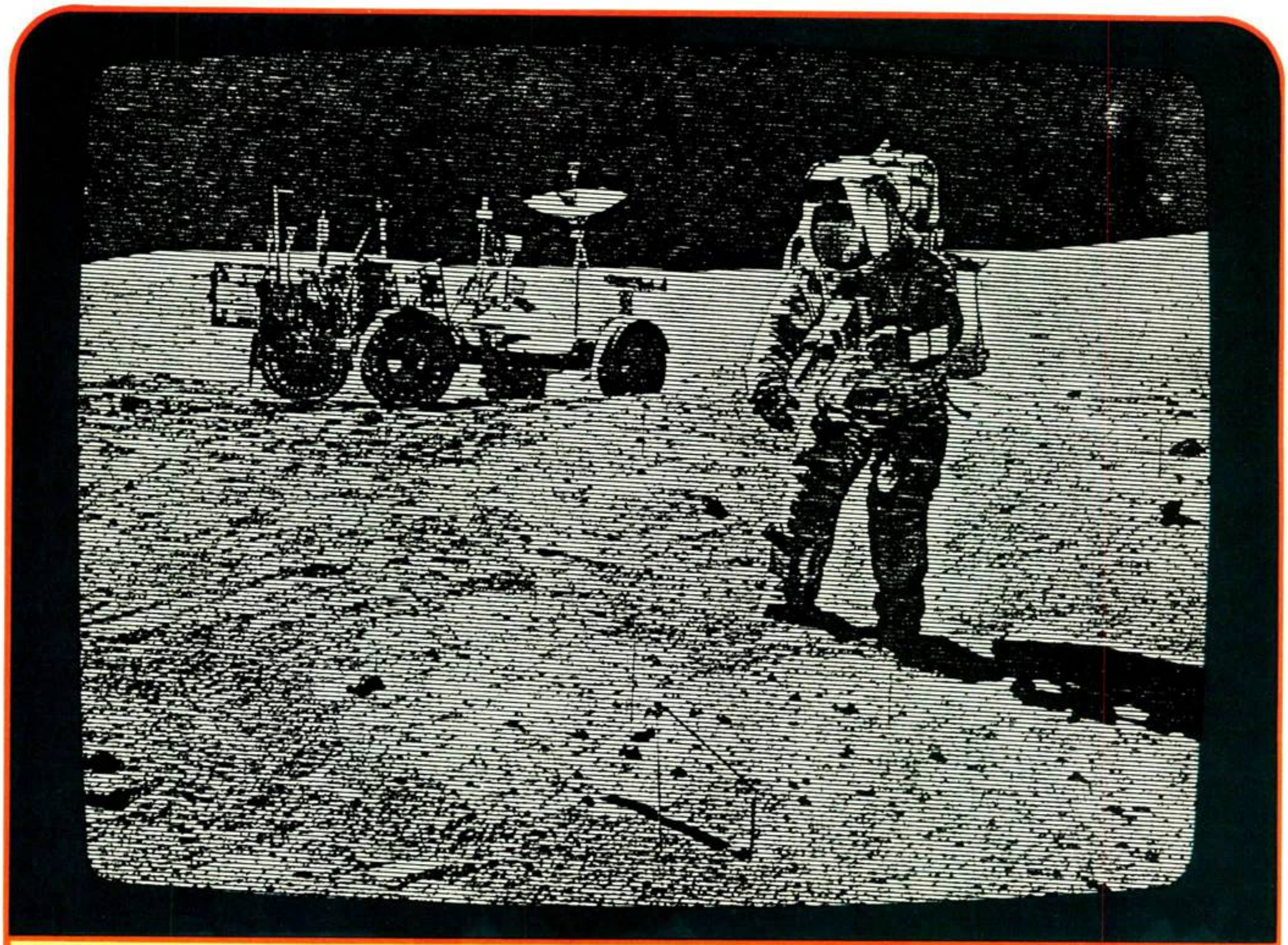


"Lunar Explorers," painting by John Clark © 1980 AstroMedia Corp.

"I'm at the foot of the ladder. The LEM footpads are only depressed in the surface 1 or 2 inches, although the surface appears to be very fine-grained...that's one small step for man, one giant leap for mankind...yes, the surface is fine and powdery. I can kick it up loosely with my toe. It adheres in fine layers like powdered charcoal to the sides and sole of my boots...I can see the footprints...there seems to be no difficulty moving around...even easier than the simulations...no trouble...."

Thus began the direct exploration of our Moon by "men from the planet Earth." Three and a half years later, they were gone again. It seems certain that human beings will return, return to explore, mine, refine, live on the Moon — but we do not know when. Apollo was the first, the vanguard, the introduction, the assurance that it can be done, the guarantee that eventually other men from planet Earth will kick up lunar dust, make footprints, call the Moon home.



The Moon Treaty

In December 1979, the United Nations General Assembly opened for signature a "Treaty Governing the Activities of States on the Moon and other Celestial Bodies," known as the Moon Treaty. Originally proposed by the USSR in 1971, the treaty has since then been under negotiation in the U.N. Committee on the Peaceful Uses of Outer Space.

This treaty, if it comes into force through the signature of five or more nations, would limit the human use of the Moon. It makes the Moon "the common heritage of Mankind," a term which many developing countries interpret to mean common property. The treaty would prevent any government, organization, or person from owning any part of the Moon's surface or subsurface, or any of the Moon's natural resources in place. It calls on governments to prevent the disruption of the existing balance of the Moon's environment by adverse changes or contamination. The treaty makes national administrations responsible for the activities on the Moon of private companies and individuals under their jurisdiction. It requires that all space vehicles, equipment, facilities, stations, and installations on the Moon, and in orbits around or other trajectories to or around it, be open to inspection by other nations.

The most controversial part of the treaty concerns resource extraction. Because no one could agree on the exact terms, the treaty includes only general principles, such as the one requiring equitable sharing among nations of the benefits derived. While the detailed rules are to be negotiated later, the clear bias in the treaty is toward an international agency for moon-mining.

The treaty could inhibit the economic use of the Moon, particularly by private companies. Because of this, and possible implications for the Law of the Sea negotiations (where a proposed Seabed Mining Authority is an issue), some individuals and groups argue that the U.S. should not sign or ratify the Moon Treaty. Senators Church and Javits have asked Secretary of State Vance to hold up further action until the treaty is reconsidered and revised. Other critics point out that the terms of the treaty apply not only to the Moon, but to *every* body in the solar system, including the mineral-rich asteroids. Signing the treaty could limit the use of the entire solar system by future generations. It might work to the particular disadvantage of the United States, whose principal economic engines are private companies.

Sun's radiation during its two-week day, and surface temperatures soar to over +200° F; in the depths of lunar night, they plunge to more than –200° F. Micrometeorites pelt the surface continually.

A terrestrial bacterium on a piece of the Surveyor 3 robot lander (brought back to Earth by the Apollo 12 astronauts) survived these conditions for more than 3 years. But if humans are to live and thrive on the Moon, they must bring a safe, artificial environment with them, or construct one from lunar materials. These will not be the temporary ecologies of spacecraft — submarines in space — but long-term habitats. If humans on the Moon are to remain healthy, productive, and sane, their living quarters should look, feel, taste — even smell — like Earth.

One of the intriguing discoveries about lunar soil is that plants grow in it if we add water, nitrogen, and trace elements — and perhaps a lowly worm or two. Lunar greenhouses could provide food for the colonists, and perhaps feed for livestock. The Moon Base atmosphere could be circulated through the same oxygen/carbon dioxide cycle we know on Earth — although someday lunar colonies may extract their oxygen directly from the rocks. Using plants, the air would have that necessary touch of moisture which prevents respiratory tissues from painfully drying up. And lunar inhabitants could watch life grow on the Moon.

Because of the expense of importing supplies from Earth and the unavailability of a natural biosphere, lunar residents will have to recycle nearly all of life's necessities, water especially. Supplies will be monitored closely with Moon Base personnel controlling the atmosphere, temperature, and waste, and carefully managing food stocks. The "disposable society" will end on the Moon, if nowhere else before.

No matter how clever and foolproof our designs, the Moon will remind us of their fragility. A puncture in a living module, the failure of an oxygen recycler, a leak of precious water — all these mean an ecology in danger. Humans on the Moon, sensitive to the basics of survival, would appreciate far better than we do the biosphere of the Earth. But their knowledge and experience will also allow us to carry Earth life out into the solar system and colonize space, unrestricted by the lack of natural biospheres.

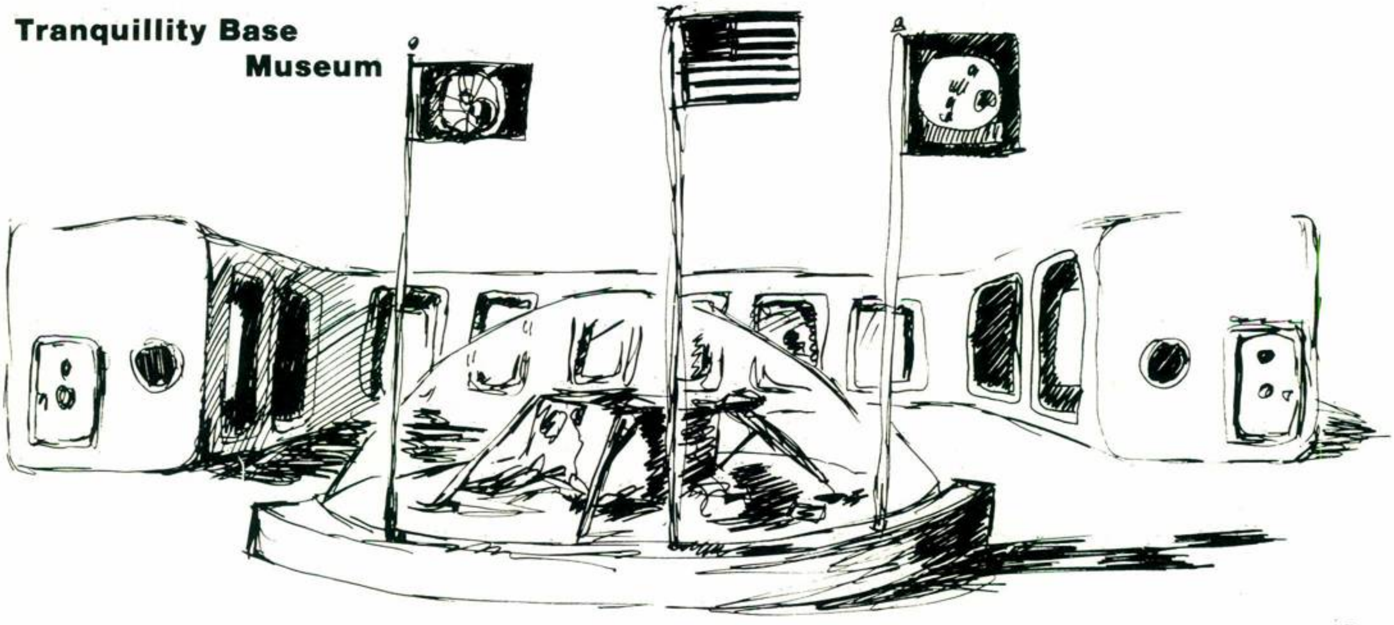
The Lunar Economy

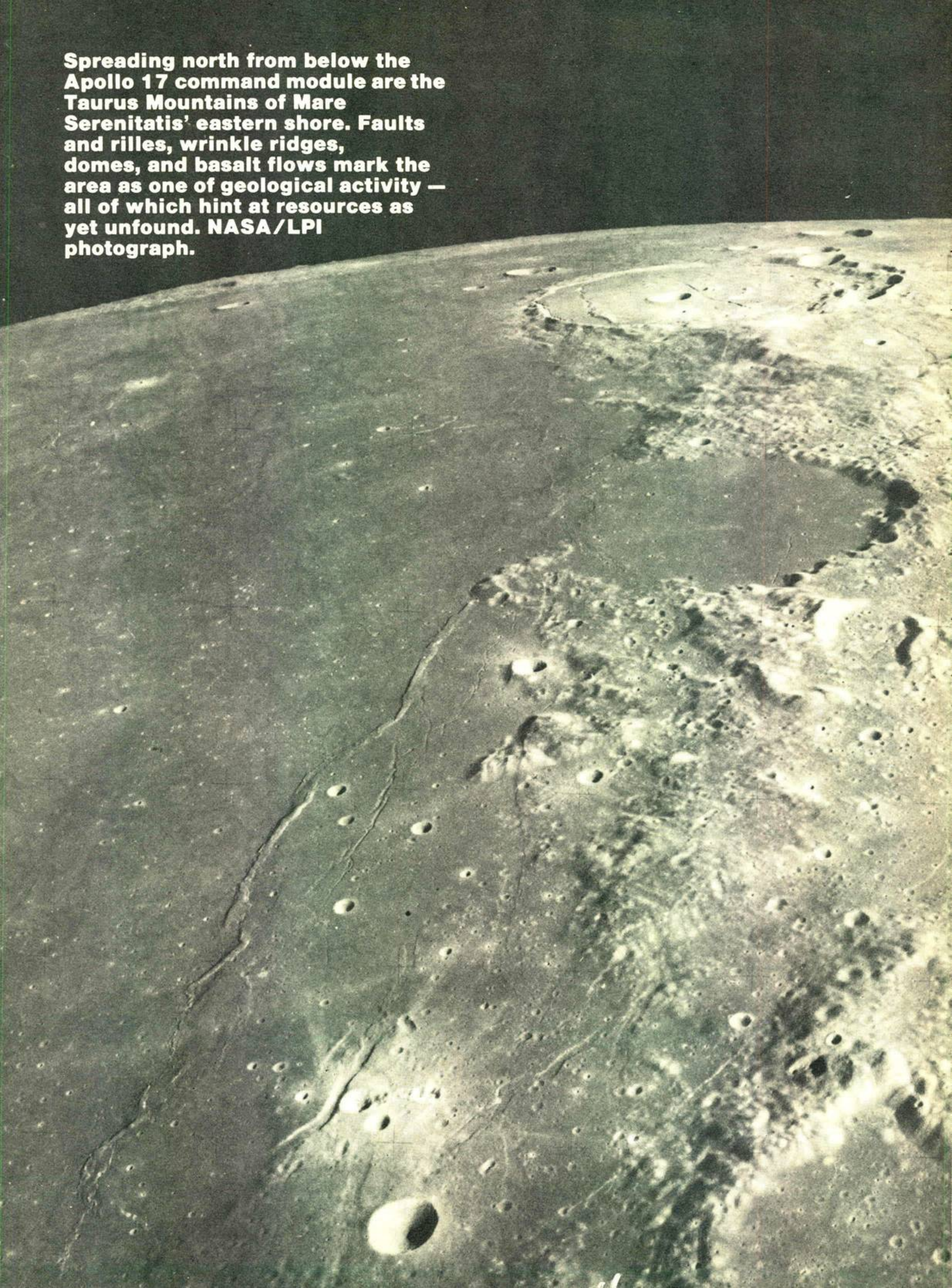
Aerospace imagineer Krafft Ehricke and industrialist Neil Ruzic have pointed out that the Moon is, in many ways, a perfect industrial environment. It has no plant or animal life; no air or water to carry pollutants; and unfiltered access to solar energy at least half the time. It has many of the industrial advantages of outer space, spelled out by Harry Stine in his *Third Industrial Revolution*: vacuum, cleanliness, a wide range of natural temperatures and radiations, and a virtually infinite sink for waste heat. In the Moon's weak gravity, more efficient industrial processes will be possible. And minerals, the feedstock of manufacturing industry, are abundant and unowned. (See the box on "The Moon Treaty," opposite page.)

Several NASA-sponsored investigations have explored potential products of a lunar industry. Dr. David Criswell of the Lunar and Planetary Institute in Houston, Texas, envisions a mix of manned and unmanned industrial operations on the Moon. "We see," explains Criswell, "a high level of automatic and remote control excavation and hauling operations, capable of transporting three million tons of ore per year to a central processing plant." Such a mining operation, says Criswell, "will not require major technological breakthroughs"; the designs will be natural extensions of Earth mining techniques.

Primary industries on the Moon, like mining, would require at least a small permanent lunar population, probably at several sites. One recently completed study describes an initial mining operation developed by 25 people in four months and then maintained by a crew of 10. Over time, mining could feed materials-processing plants and secondary industry, producing a technological crop of solid-state electronic devices, new compositions of fiber and foam, and possibly panels for satellite solar power stations. Experiments conducted by the Materials Science Department at UCLA have demonstrated that glass and ceramic articles can be

Tranquillity Base Museum





Spreading north from below the Apollo 17 command module are the Taurus Mountains of Mare Serenitatis' eastern shore. Faults and rilles, wrinkle ridges, domes, and basalt flows mark the area as one of geological activity — all of which hint at resources as yet unfound. NASA/LPI photograph.

made from mineral mixtures identical to those in Apollo samples, even spinning moon soil into glass wool.

Miners and production line workers would want wives or husbands, children, doctors, teachers, cooks, air conditioning mechanics, even police. The lunar economy would create lunar communities, perhaps first in company towns. Thus would begin — probably unintentionally — the colonization of the Moon. As the new Lunarians sought to make those cities more comfortable, they might build domed underground environments with giant, meteorite-resistant skylights providing natural illumination during the lunar day.

Lunar industry would need transport to take its products to market, perhaps space tugs capable of pushing payloads to Earth orbit. But there may be a cheaper and engagingly simpler way. Given the Moon's weak gravity and lack of atmosphere, it takes only 1/20 as much energy to lift materials to escape velocity from the Moon as from the Earth. In 1950, Arthur C. Clarke suggested that electromagnetic launchers on the Moon be used to hurl cargos into space. If our most mineral-intensive industries were located in orbits around the Earth or Moon, they could be fed a steady diet of lunar rock at a modest energy cost.

Moon mining could support new Pittsburghs in space — and possibly large habitats like those visualized by Princeton physicist Gerard O'Neill. Space factories and colonies would be the core of the orbital civilization foreseen by former astronaut — now Senator from New Mexico — Harrison Schmitt. These space cities would be constructed more cheaply of lunar rock than of minerals lifted out of the deep "gravity well" of the Earth. It was O'Neill who said that space colonization could not have been proposed seriously without the Apollo samples.

Once raw materials and finished products begin to flow from the Moon to the Earth and to habitats in space, a triangular trade will spur continued growth, allowing Moon colonies to finance their continued existence without further depleting the Earth. Sometime early in the next century, we may see goods stamped "made on the Moon." That island economy, a "workshop of the world," might someday rival the industrial nations of Earth. Its enterprises could carry the diversity of human civilization into the solar system.

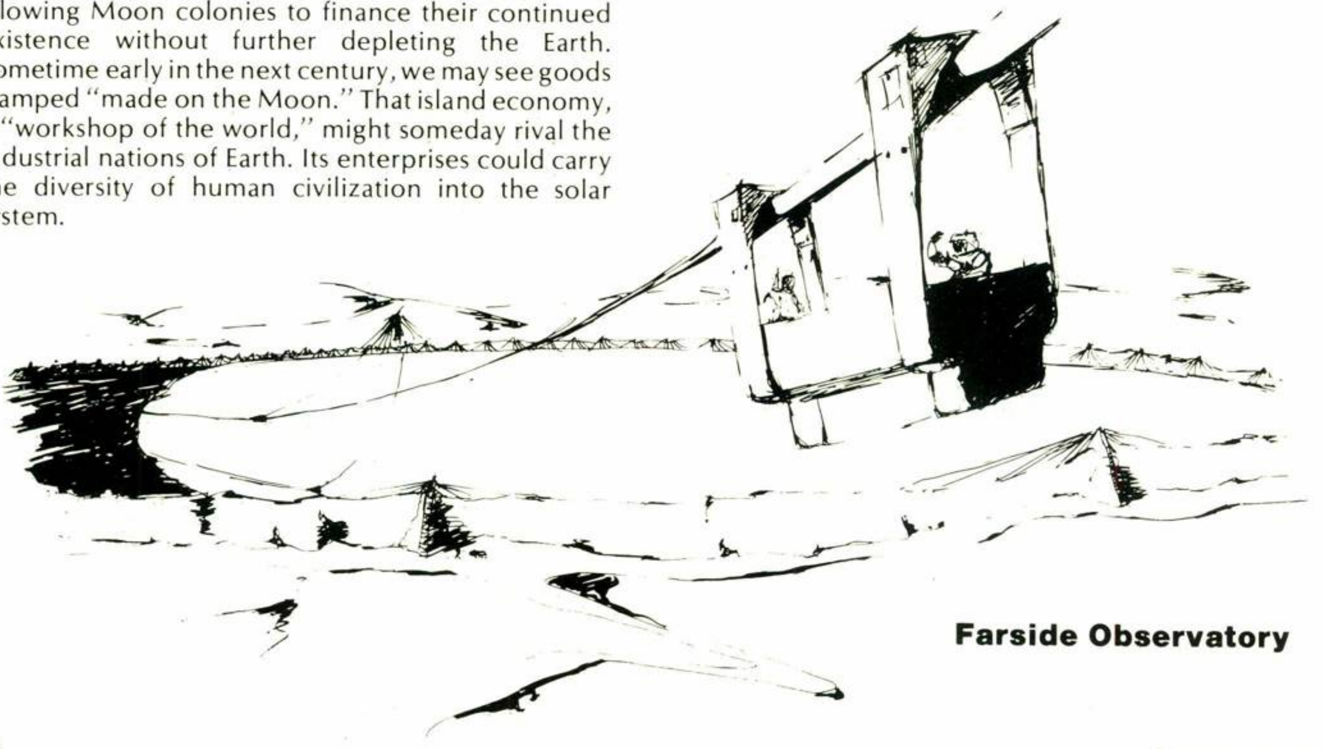
Other Uses of the Moon

Because the Moon is insulated from the Earth by distance and vacuum, it has been suggested as a testing area for dangerous experiments and technologies. NASA and Department of Energy studies have looked at storing some forms of nuclear waste from Earth's reactors on the Moon, with the crater Bailly already scouted as one potential site. Lunar laboratories might be the safest place for genetic experiments on new and perhaps virulent forms of life and for the examination of any organisms found elsewhere in the solar system. Nuclear engines, one method of carrying humans to the planets and beyond, could be tested in far-off corners of the Moon.

When Earth-Moon transport costs come within the reach of wealthy individuals, as round-the-world air fares already have, Luna may become an attraction for ambitious tourists — some of whom now visit Antarctica. On the Moon, they could see the universe as it really is, read by earthlight, and admire their home planet from afar. The more fortunate tourist who timed his visit well could see a shadow cross the face of the Earth as the Moon passed between our planet and the Sun, or even more spectacular, when the Earth passed in front of the Sun.

Moon tourists could gambol in light gravity, or careen across the lunar seas in speedy cars. In lunar caves and domes, visitors could achieve human-powered flight if they wish, without elaborate effort or training. Sports in low lunar gravity might be so remarkable as to command television audiences on Earth, with soaring athletic leaps and fantastic, floating ballets.

Even that timeworn cliche, the "Guided Tour," could happen; tourists will want to see historic landing sites: the early robot explorers such as a Surveyor lander — its accordion arm still outstretched — or a Soviet Lunokhod, its wheels stilled forever. But every tour would culminate in the Sea of Tranquillity.



Farside Observatory

There visitors would view the site of Apollo 11, preserved from micrometeorites and future Kilroys by a transparent dome. Small signs would denote points of interest: discarded, antiquated-looking astronaut backpacks, a U.S. flag standing taut, deactivated scientific equipment, and a slightly charred four-legged pedestal that once supported the ascent stage of the lunar module Eagle. Attached to one leg, a plaque with simple words: "Here men from the planet Earth first set foot on the Moon. July, 1969, A.D. We came in peace for all Mankind." Below it, captured in the dust of eons, the first footprints from another world.

Homo Lunaris

When humans first went to the Moon, their bodies came back almost unchanged; only their perceptions had been affected. But long-term residents of the Moon will lose muscle mass in the lighter gravity. Their bones may partly decalcify, and their metabolisms alter, under the body's lesser workload. Eventually their muscle structure will be adapted to the Moon rather than to Earth, making the same physical task more strenuous than when they arrived. Scientists estimate that after five years in lunar gravity, people assigned to the Moon will not be able to return safely to the Earth.

The first children born on the Moon will have developed in a low-gravity womb; their body's chemical signals may produce taller, more slender humans. By growing up on the Moon, lunar people might isolate themselves permanently from the Earth, whose gravity would be a crushing burden.

Born on the Moon, adapted to it, feeling it to be home, "Homo Lunaris" will identify more with the Moon than with the Earth. Raised in a lunar environment, they will have different attitudes, different values, and the beginnings of a different culture. When visitors come from Earth, moon people may find them clumsy, overmuscled, and insensitive to the austere beauty of the silent world — and to the delicate balances of Luna's closed ecologies. This alienation from Earth is likely to grow as physical appearances diverge.

Moon people will be conscious of their tenuous existence at the end of a long supply line from Earth, and might feel a sense of relief each time a freighter descended to Moon Base with supplies. They would know that their survival depended on continuing support from another planet, and on political and financial factors beyond their control. As long as the Moon's inhabitants are on temporary assignment, they will accept this as normal. But attitudes will change as the Moon acquires permanent inhabitants. Lunar humans will worry about the interruption of their future by events on Earth, the drying up of their pipeline through space. They will have every motivation to make themselves as independent as possible by innovative use of lunar resources.

The scarcity of certain elements on the Moon — particularly hydrogen, nitrogen, and carbon — will require the import of materials, perhaps eventually by mining certain volatile-rich asteroids. Most of all, the Lunarians will need water. Its oxygen component is abundant on the Moon, but the hydrogen needed to manufacture water appears to have escaped, suggesting a need for liquid hydrogen tankers from the Earth.

Project Farside

At first glance, the far side of the Moon seems as remote and useless a location as you could imagine, but it may be ideal for conducting the search for extraterrestrial intelligence.

An analysis by the Stanford Research Institute (SRI) proposes using lunar craters on the far side to hold radio telescope dishes. The concept would be similar to that used in the 1,000-foot radio telescope at Arecibo in Puerto Rico. With their remarkably uniform shape, young, deep, bowl-shaped craters offer the choicest spots for Arecibo-type antennas.

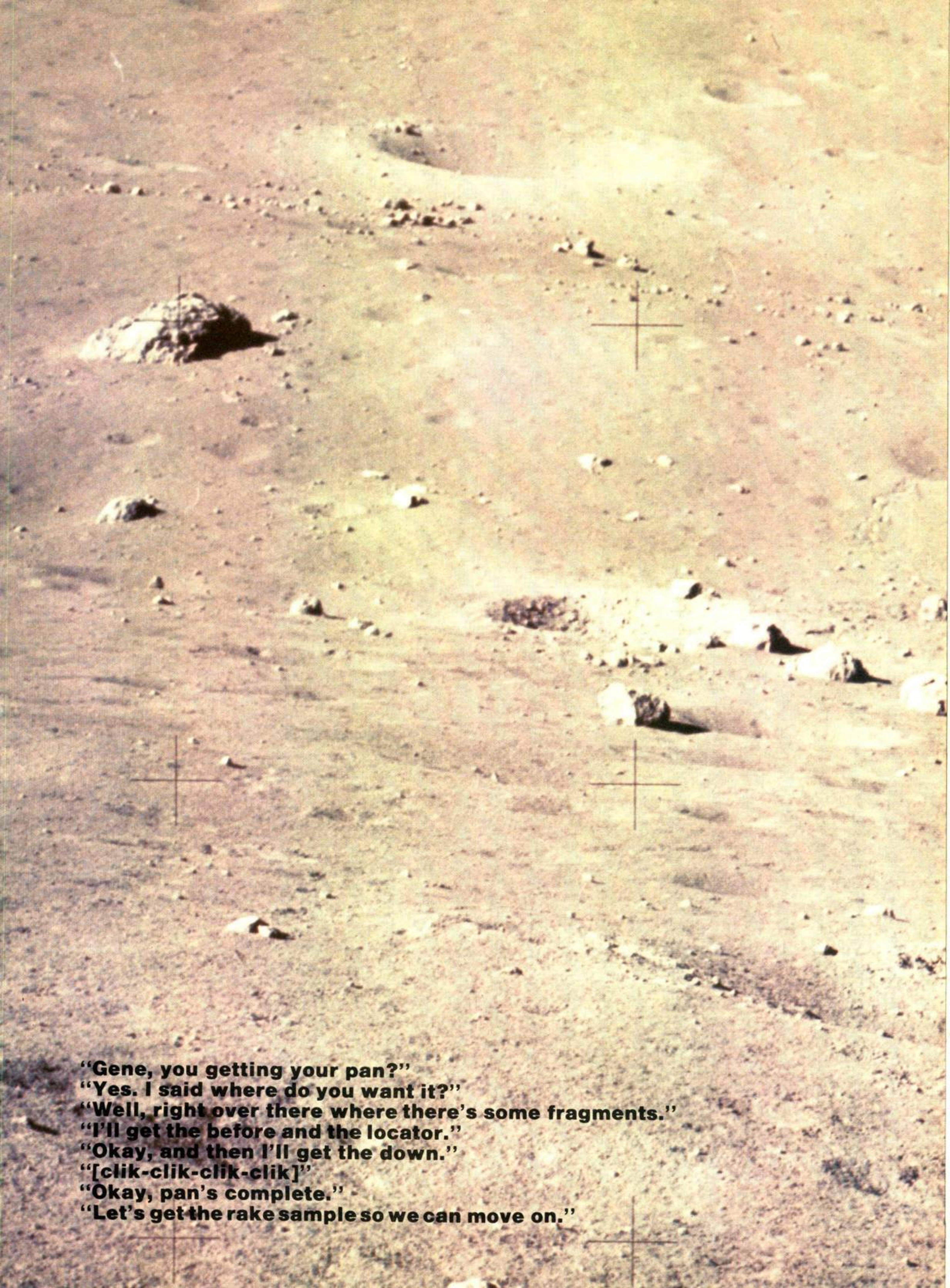
The SRI study argues that the Moon's weak gravity and lack of atmosphere will allow improved antenna design, with no need for towers supporting feed systems of radio telescopes as here on Earth. Selected craters need be only partially filled with reflector material, while both the antenna feed and dish would be suspended on long cables extended from a crater rim. The Moon-based antenna system could be built from locally available materials, cutting costs.

Another option is to construct a field of large radio dishes similar to that visualized in the NASA study Project Cyclops. Using aperture synthesis, these receivers would have the sensitivity and resolving power of a much larger instrument.

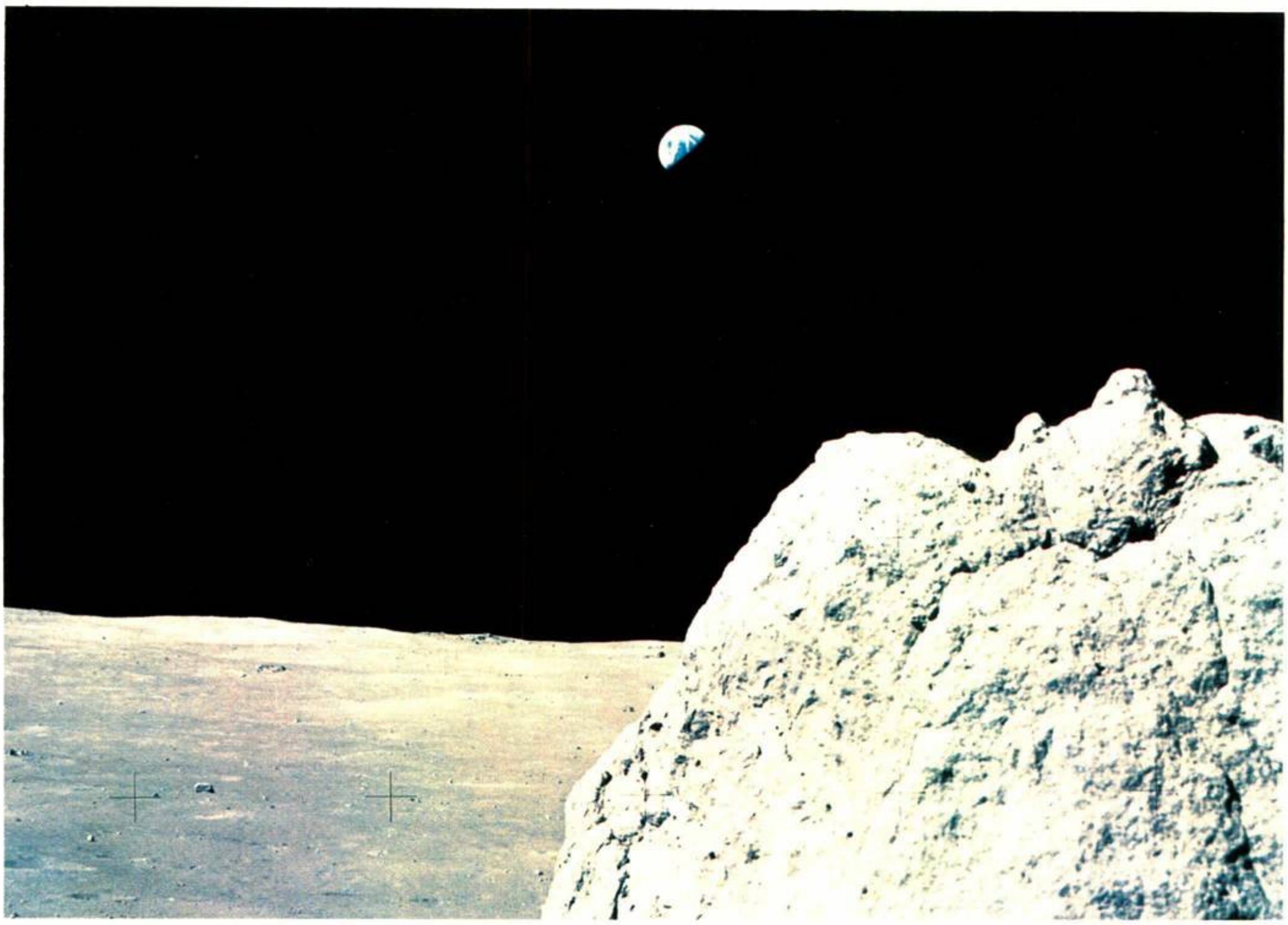
Tucked away on the Moon's far side, the antennas would be shielded from the buzz and crackle of earthly interference by over 2,000 miles of rock. Sifting through countless stars for the whispers of other civilizations, astronomers using the antennas would make many new discoveries, because their capabilities would far exceed the limitations of terrestrial systems. Project Farside, complete with optical telescopes and other sensitive astronomical equipment, would open our eyes and ears, revealing the universe as never before.

Fortunately, lunar scientist Dr. James Arnold of the University of California at San Diego sees "an excellent chance" of finding a large reservoir of water ice and frozen gases on the Moon, equal in volume to one of the smaller Great Lakes. If they find no ice lodes, moon people could follow Isaac Asimov's advice and divert a small comet nucleus into orbit around the Moon, drawing on that dirty snowball the way Eskimos use a beached whale.

Sooner or later, moon people will seek autonomy from the Earth. British space expert Bob Parkinson estimates that the moon colony must grow to at least 2,000 people to achieve self-sufficiency; that might happen during the first half of the 21st century. Even then, earthbound societies would have powerful tools of influence and control. But if they eventually do establish themselves as a distinctive civilization, the people of the Moon — perhaps allied with autonomous colonies in space — could begin the rediversification of Man.



"Gene, you getting your pan?"
"Yes. I said where do you want it?"
"Well, right over there where there's some fragments."
"I'll get the before and the locator."
"Okay, and then I'll get the down."
"[clik-clik-clik-clik]"
"Okay, pan's complete."
"Let's get the rake sample so we can move on."



As we look back at Earth from the Moon, we feel warmth, friendliness, and a sense of home. Yet how will lunar citizens view the ancestral planet? Will they too feel what we do, or will they just think of it as a nice place to visit, but too cramped, crowded, hot, heavy, and humid for decent living? NASA/LPI photograph.

The Second Sphere

A few decades from now, Earthlings may be able to see flashes of light on the Moon through their telescopes, or reflections from metal structures in lunar orbit. Over the years, these signs of human presence will spread across Luna's face, points of life scattered over the barren land, perhaps reaching around to the side never seen from Earth. There, a Farside Observatory will house powerful and sensitive tools for astronomy, undisturbed by atmosphere or signals from Earth. As NASA scientist Dr. Bevan French comments, "It's nice to know there's one place in the solar system where we won't hear TV commercials." A Stanford Research Institute study has suggested designs and locations on the far side for giant radio antennas to listen for the radio whispers of extraterrestrial civilizations. A 40-inch optical telescope on the Moon could discern objects as small as any now seen by the 200-inch instrument on Mount Palomar in California.

By the time Farside Observatory is a reality, the space between the Earth and the Moon will be busy with ungainly, workhorse shuttlecraft, sailing from orbit to orbit and down to colonies on the surface. On the Moon, in caves and tunnels and domed lunar cities, plants and animals will grow, reproduce, and reach into new ecological niches. As humans tunnel out more of the Moon, they will carry life with them, spreading it around that airless ball of rock, giving life another foothold in the solar system. As lunar industries vent gases to the outside, some molecules will be held by the Moon's gravity, forming the beginnings of a lunar atmosphere. We will, without question, change the Moon, but so will the Moon change us.

The average citizen of Earth may sense no historical transition. To him the Moon will be just another part of the evening news, an expensive area code to dial. But images of humans on the Moon will remind Earth people that their future is not limited to their planet of origin. Almost without realizing it, they will have added 14 million square miles of territory, four times the area of the United States and about equal to North and South America together — the New World of history. Those with perspective may recall the Apollo project not just as a technological high-water mark of the 1960s, but as a moment when we unknowingly guaranteed the future of humankind.

Michael Michaud was the State Department's representative on national space policy issues between 1976 and 1978, and was the principal author of a study on long-term economic activity in space for President Carter's Science Advisor. Leonard David is a free-lance writer and a senior editor at Aviation/Space *magazine. He is also doing part-time work on solar power satellite planning.*

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Astronomy on the Sidewalk

John Dobson, the subject of this interview, lives in San Francisco.

Q: Rumour has it that you were born in China?

A: That is true. I lived there till I was twelve, and my youth was spent on that side of the Pacific.

Q: You didn't practice astronomy there, did you?

A: Not much; but my dad had one of those little refractors, two or three inches in diameter, one of those things that really telescopes out, you know, and I used to look at the moons of Jupiter with it. That's what used to fascinate me in those days, the planets, things like that. I really had no notion of what we call "deep-sky" astronomy today nor any idea what the whole universe was about. Later, when I was in grade school in San Francisco, I did drawings of the moons of Jupiter night after night. I would look at them and then draw them on big blue sheets of paper for some kind of a project.

Q: How old were you when you first took a truly active part and interest in astronomy?

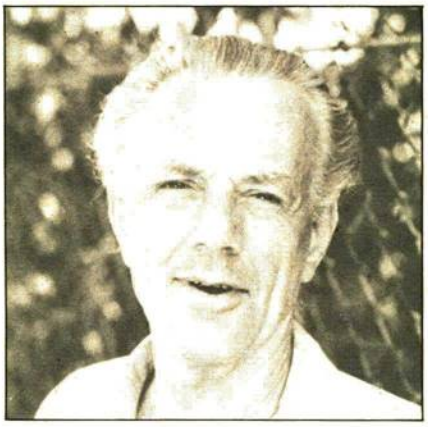
A: I was born in 1915, so in 1945 I was thirty...it was after I was thirty.

Q: What was it that led to an interest beyond the general curiosity of which you spoke before?

A: What I was interested in at that point was Indian philosophy, *Advaita Vedanta. Advaita* means non-dual. *Vedanta* means the culmination of knowledge. All Vedantians hold that there is only one supreme Being behind this universe. One school teaches that that Being has become this universe by transformation. The non-dualists hold that nothing has happened to that Being, but that we have mistaken it for the universe. Nothing has happened.

Q: I could see how such philosophies could lead quite naturally to the study of astronomy. Tell us the step that took you there.

A: Well, you see, those people have a cosmology. They try to understand why it is that we see that Being the way we see it. Why do we see it this way and not some other way? I had joined a monastery at that time and stayed with the Advaita Vedantians first in San Francisco for fourteen years and then in Sacramento where we were building a center — twenty-three years in all. Even though I was raised in China in a Methodist mission, I soon became an atheist. I was a real atheist at first, after I had heard Swami Ashokananda, the monk "beyond sorrow." That's how his name translates from the Sanskrit. If the philosophers are right, and if the scientists are right, when we talk about this world — and there is only this one world to talk about — then they have to agree.



Q: How does astronomy fit into all this?

A: You have to see the universe in order to understand it and if you don't see it, what is there to explain?

Q: Did this in some way lead to your preoccupation with the San Francisco Sidewalk Astronomy project?

A: It led directly to it. What I first wanted to do was to see for myself, so with a friend I made a telescope and when I looked at the Moon through that thing I thought, "Oh my God, everybody has to see this."

Q: This first telescope you built, was that what has later become the Dobson mount telescope?

A: It was an ancestor; we do it much better now.

Q: At what point did you stop looking for yourself and start to show the heavens to others?

A: As soon as I became aware that it was possible to see those fabulous details through a telescope which you could make yourself, I became interested in having everybody see them.

Q: A commercially-bought instrument never entered your head?

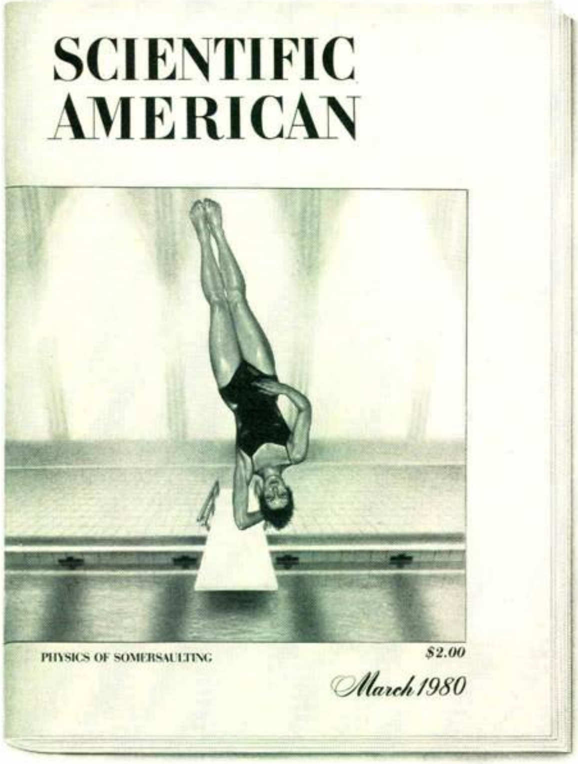
A: No, it never entered my head because I never had any money. In the monastery you don't have a penny.

Q: How did you go about grinding your big mirrors?

A: With the first mirror, I didn't really know how to figure it. I just did what it said in some books and tried to test it with a Foucault tester and all. Later on, in Sacramento, I had no access to anything like that, so I tested on the stars. I used the stars as a light source, threw the eyepiece out of focus, and learned from the distribution of light in the out-of-focus disks what was the matter with the mirror. Then I did corrective polishing.

Q: That would be the empirical method, wouldn't it?

A: Surely it was empirical. But by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March 1980

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Q: Am I correct in assuming that you literally had to pull your mirrors out of the telescopes, again and again, to repolish them?

A: Surely, sometimes we had to do it hundreds of times. So we made the telescopes so that the mirrors come in and out very quickly — very, very easily. We just take two screws out of the tailgate, and you can take the mirror out in about ten seconds. We don't use grinding machines. We use elbow grease. I know it says in the books that it takes hundreds of hours, but it really doesn't. It takes about ten hours to grind a 10-incher. It took us only nineteen to grind and polish the 24-incher.

Q: Let me go back for a moment to your very first mirror. How did you go about that one?

A: I just got two porthole glasses and ground one against the other with carborundum in the overhang position. The middle of the top one grinds faster and the edges of the bottom one grind faster, too.

A friend of mine, who had borrowed a very small book with rather incomplete instructions from the public library, and I simply went on that. I followed the instructions to the letter. I had pitch in my hair, in my eyes, down my neck, and all over my clothes.

Q: Was the first mirror an accurate one?

A: Not by our present standards. I had no other mirrors with which to check mine. I had never looked through anybody else's telescope. But I would not quit working on a mirror until I could see the surface details on the top of the galvanized nails that held the "High Voltage" signs on the power poles two blocks away.

Q: Was that the "Dobson test"?

A: I suppose. What you really want to do, in order to find out what's wrong with your mirror, is to look at one of those bright spots of reflected sunlight on the insulators on the power pole out of focus. If the mirror is a paraboloid, the distribution of light in the out-of-focus disks is the same inside of focus and outside of focus.

Q: How many telescopes have you built to date?

A: I, myself, have actually built only a few dozen, but I have helped a lot of people build telescopes. Before I left the monastery, I'd already figured something like fifteen 12-inchers and two 18-inchers and a whole lot of smaller stuff.

Q: When did the name "Dobson Mount" first find its way into the astronomical vocabulary?

A: The term "Dobsonian Mount" crept into the vocabulary only a few years ago and I don't even know where it started.

Q: Would you describe the basic characteristics of the classical Dobsonian mount?

A: It's just a nice, simple alt-azimuth mount, usually built out of plywood, in which the lower bearing runs on teflon and the trunnions rest on teflon too. It works just the same as military guns. On each side they have trunnions so that you can aim the gun up and down, and it turns on a merry-go-round bearing underneath. Theirs run on ball bearings; we run on teflon, that's all. Like the military, we don't want any backlash in our bearings. When we push the instrument to the right, we want it to stay there and not come back on its own.

Q: Isn't it strange that a person as pacific as you should refer to ordnance for guidance in astronomical matters?

A: I really didn't know that I was copying gun mounts when I invented this concept. I found that out afterwards. The reason they are the same is the requirements are identical, and this is the simplest solution to the problem.

Q: Do you remember the first time you took one of your telescopes to a public place to share the sky with other people?

A: I don't think I remember the very first time, but up in Sacramento I had a 12-incher which I used to wheel around the neighborhood during daytime, usually when the Moon was first quarter. The kids in the street would ask me, "What's that?" I'd say, "It's a telescope. Do you want to borrow it?" Of course, they would say "yes," and they would take me to their mother's house and mother would probably not let me in the garage because she did not know me. If mother knew me, everything was cool. Otherwise, we'd look around the neighborhood for some other kid's mother who did not mind having a 12-inch telescope in the garage. Then I'd steal away from the monastery at night to set up the instrument and explain, at the eyepiece of the telescope, what people saw.

Q: A real Pied Piper. How large did those crowds get?

A: That's exactly what they called me: the Pied Piper. There usually were a few dozen kids standing around, some with their parents.

Q: When did adults first come into the picture?

A: It's always a mixture and depends where you are. In national parks you have a predominance of adults.

Q: How many people, would you guess, have looked through your telescopes up to this time?

A: It will be more than a million by now. We've had something like a hundred thousand people a year looking through our telescopes and we've been doing it now for more than a decade.

Q: And it goes without saying that you do all this without charge?

A: Yes, it goes without saying. Sometimes people have suggested that we make a charge, but there isn't a single sidewalk astronomer that I know of who would be willing

SIDEWALK ASTRONOMERS

to do that.

Q: To be crassly commercial for a moment, how do you get funding for your project?

A: For the first few years, in fact most of the way through, we've done it on our own money. At first we used Brian's money. Brian Rhodes is a mechanic, but he got so involved with what we were doing, first with building scopes and then with taking them on summer tours, that he got fired from his job. He was the backbone and guts of the sidewalk astronomers even when he was broke. Brian first had an 8-incher and the day we figured that, he took glass for a 16-incher which became the workhorse of the sidewalk astronomers. Very soon after that he and I built the "twenty-four," which we took to so many national parks. Now, fortunately, Brian is re-employed.

Q: What would it take in terms of money to do what you do right?

A: Probably for something like ten thousand dollars a year we could do what we want to do properly. We need approximately half of that to run the telescopes around the national parks, state parks, and all those other locations, with volunteers to manage them, and then we need other money to keep the instruments out of the rain when they are staying in the city. Right now our old bus with the trailer for the 24-inch behind it is parked in Marin County, and last time I went over to check it, I found that a brake drum had been thrown through one of the windows. It's parked near school buses, but we cannot prevent vandalism. The 24-inch telescope and the tube for the 22-inch are in the bus. Rain has done a lot of damage and much has to be rebuilt.

Q: Who exactly are the San Francisco Sidewalk Astronomers?

A: The sidewalk astronomers are just a group of enthusiasts who like to see to it that the public learns more about astronomy, both observational — that is, they get a chance to see the universe — and educational, that they learn about the heavens. We do several things in those directions. We give slide shows, especially in national parks, so that people know what they are about to see, and then, of course, we talk at the eyepiece about the objects actually being viewed.

We also give programs for schools. We have only two rules in our bylaws concerning membership: We have to like you and you have to like us. The dues are only ten dollars a year. There are about 100 members all over the world. If you want to join, just mail your membership fee

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to the San Francisco Sidewalk Astronomers, 1600 Baker Street, San Francisco, CA 94115.

Q: Do you actually still put your telescope up on the sidewalks of San Francisco?

A: Oh, we do it all the time. Just before I came to Los Angeles, we had telescopes out on Christmas night and the night after at Ghirardelli Square. We don't put the "twenty-four" out, because it's much too big for use in the city, but we had our "Psychedelic Giraffe" (that's a 10½-incher) and some others.

Q: What are the objects you pick for viewing?

A: In the city, we're stuck with the planets and the Moon. It would be unfair to show the public the Orion Nebula. Sometimes they ask for it, but I tell them that this does not count as having seen it because you can only see the bright patch.

Q: Since these are all "undriven" telescopes, how long do objects stay in the field of view before you have to move or push them along?

A: Usually about three viewer's worth. In the "Psychedelic Giraffe" at a hundred power or so, you can just see the whole face of the Moon. That's half a degree. It drifts through in about the time it takes for three people to get a pretty good look. If viewers are slow, you have to allow for it. Sometimes, when the weather is fabulous, they simply won't come down from the eyepiece, so you show them how to move the telescope themselves.

Q: What do people say who stand in line when that happens?

A: They're not that impatient. They know that they'll get preferential treatment too, when they get to the eyepiece.

By the way, our telescopes *are* driven. They run on yoghurt. I eat yoghurt. Once at Jackson and Broderick Streets, many years ago, I apologized to a couple of young ladies for the fact that the telescope did not follow the objects in the sky and that I had to pull it around all the time. "Oh, no," they said, "we wanted to see the spin of the Earth like that..."

Jackson and Broderick brings back many memories. I was there for years with a telescope, every clear night. We didn't have a ladder to climb on in those days, and so we used one of those big square street litter cans and people climbed up on the lids. Sometimes they literally jumped up and down with joy until they broke them. I was fresh out of the monastery then and had no place to stay, so friends would put me up one after the other. I used to eat weeds and wildflowers for lunch and would be fed other meals by good friends.

Q: Do you remember some of the things people have said when they first looked at some celestial object?

A: People say funny things at the telescope. One time a gentleman looked at the quarter moon. He looked for a long, long time without saying anything. Then he turned to me and said, quite seriously, "It's in bad need of repairs."

Q: Besides national parks, the sidewalks of San Francisco, and schools, where do you set up your scopes?

A: During the winter we've gone to Death Valley for the last seven years or so. There we set up near the visitors' center. There are some comments I remember which one gentleman made there recently. He said, "When one goes to an observatory, you can look through one instrument, at one object, and that is all. Here you have nine different telescopes, trained on nine different objects, and we can see even more if we like." In the winter sky, there are such wonderful things to see. You can see the Crab Nebula with the stars in it; you can get three galaxies at a time: M-31, M-32, and NGC-205 in a smaller telescope at low power. There's always some planet, perhaps a crescent moon, and then, of course, the Orion Nebula. M-42 from Death Valley, through the twenty-four incher, is absolutely fabulous. It more than fills the eyepiece and you can see the colors: the green of the oxygen in the central bright regions, the colored lines, the bat wings in pink, and of course the stars, not burned out as in some photographs. I've never seen a photograph which shows the Orion Nebula as it really looks through our big telescope, as seen from a good place.

Q: You wax lyrical as you talk about the heavens.

A: The heavens are truly lyrical. It's not anything that we've made up! But that's really the main function of the sidewalk astronomers — to make it possible for the people who live in this world to see the world in which they live. It is useless to go through this world blind. I remember one lady, also at Death Valley, who came up to me on our last evening there, and said, "How much longer are you going to be here?" I told her that we had to leave the next day, to which she replied, "Can you stay one more day? I'll drive to Los Angeles and get my kids."

Q: What does the future hold for your stargazers?

A: We hope to expand our program. We have been given a five-hundred dollar grant by one foundation for unspecified spending, and fourteen-thousand dollars by the Skaggs foundation for buying a vehicle with a tailgate lift to get handicapped people to the eyepiece, and also for repairing the mountings of the 22 and 24-inch instruments.

But we have no traveling expenses yet. If we can get enough funding for traveling, so we can run the equipment, then we expect to go to the Grand Canyon again this summer. We entertained twenty thousand people there last year. We also would stop at several other national parks on the way there or on the way back, and also to one or two Indian reservations, as we've done in the past.

Q: Have you ever thought of writing down what people say or exclaim when they first look through your telescope?

A: I have thought about it, but there are way too many things. At the corner of Jackson and Broderick years ago, there used to be some French girls who came to look. "Incroyable," they used to say; that's where I learned that word. There was one lady who also had a strong French accent, and she told me, "This could only happen in San Francisco." Then she thought for a moment and added, "No, maybe it could have happened in Peking." At which point I burst out laughing — because that's where I was born.

Q: We have gone full circle. One last question: Why were you born in Peking?

A: Well, my father was a zoologist. He went to teach zoology at Peking University, which was founded by *my maternal grandfather.*

Ben Mayer
Los Angeles, CA

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sky
almanac

pluto at opposition

As the sky darkens on April evenings, Orion is well past the meridian, heralding the departure of winter skies. High in the east are two fine observing subjects: Leo, with its retinue of planets, and a little farther to the east, the Virgo-Coma Berenices "realm of the nebulae" wherein are spread scads of galaxies. Say good-bye to winter and welcome spring's delightful sights!

Mercury

Mercury's appearance this month will be a disappointing one; although it lies at greatest western elongation (separation) from the Sun on the 2nd, and even though this elongation is the widest (27.8°) for the next 7 years, observers in northern latitudes won't see it very well at all.

On the morning of the 2nd, Mercury will be only 1.7° high (azimuth 101°: just south of east) 45 minutes before sunrise. At magnitude +0.5, you'll have a very difficult time finding it so low in the brightening morning skies.

This paradox comes about because the ecliptic, the path the planets all remain on or close to, makes a very shallow angle with the horizon as seen from midnorthern latitudes at this time of year. Thus, even though Mercury is fairly widely separated from the Sun, little of that elongation angle becomes elevation to place the planet favorably for your viewing.

Venus

Venus, too, reaches greatest elongation from the Sun this month — on the 5th, only 3 days after Mercury — but since the elongation is to the east, you will find it in the western sky after sunset.

Unlike Mercury, Venus will hardly be difficult to find, unless you just haven't recognized that bright beacon high in the west for what it is! Unmistakable once you have identified it, Venus' brilliance looks unreal.

At this time Venus will be sweeping by the Pleiades star cluster, passing it only a degree or two to the south. Go out with a pair of binoculars or a low-power RFT and enjoy the sight as the sky darkens; this will be a very pretty conjunction.

At higher powers in a telescope, Venus' shape will resemble a half-lit, featureless white ball. Its diameter on the 5th will be 23.5 seconds of arc and its brightness -4.0 magnitude.

Over the course of April and May, Venus will move down closer toward the horizon and the Sun. As this happens, it'll brighten and grow larger in apparent diameter, though its phase will shrink to a slim crescent. On May 9th, the two effects will combine to produce a greatest brilliancy of -4.2 magnitude.

Moon

Midevening on the night of April 17th-18th, a two-day-old Moon will pass through the Hyades Open Star Cluster, occulting members as it goes. Of the stars occulted, first magnitude Aldebaran is the brightest and its occultation the most easily observed.

This event can only be seen by those observing west of the Rockies; if you live farther east, the Moon will have set for you by the time the Aldebaran occultation happens. (But you'll see other Hyades stars being temporarily snuffed out before the Moon sets.)

Mars

During the first week of April, Mars will be slowing its westward motion against the background stars of Leo. On the 7th, it'll halt and thereafter begin moving back eastward toward Regulus, Jupiter, and (more distant) Saturn.

Mars' ruddy hue is very distinct and, when compared with brighter Jupiter's white blaze, you should have no trouble identifying which planet is which. Likewise, Mars' brightness (0.0 at midmonth), is about a magnitude and a half more than Regulus.

In a telescope, Mars still offers a relatively good view, though you'll need steady seeing and high powers to discern very many martian surface features. On the 1st, its angular diameter is 11.7 seconds of arc; by the 30th, 9.2 arc-seconds. We are looking down on about the 20° N parallel of latitude; the martian summer solstice comes around April 10th.

Asteroids

1 Ceres sets around 8 p.m. local time on the 15th and is at 2^h49^m, +12°04' (1950 coordinates). It's at 8.3 magnitude.

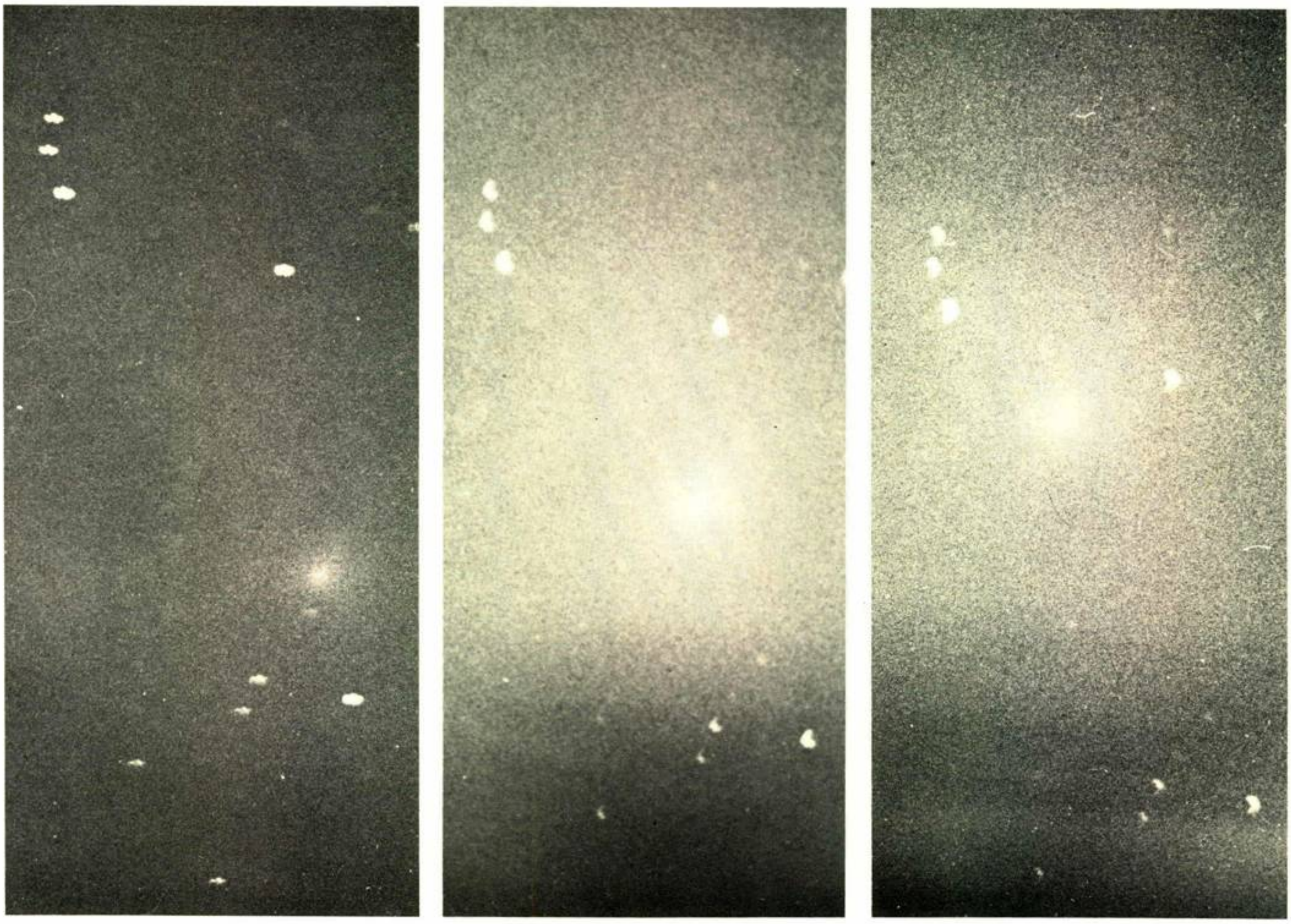
may previews

4	Jupiter 0.8° south of Mars Eta (η) Aquarid meteors
7	Last quarter moon
8	Venus at maximum brilliance
13	Mercury at superior conjunction
14	Uranus at opposition New moon
15	Occultation of Aldebaran
21	First quarter moon
29	Full moon

The conjunction of Mars and Jupiter will be the third and last of the series that has been happening since last December. Two days prior, the little triangle formed by Mars, Jupiter, and Regulus will be smallest.

The Eta Aquarids produce a moderate shower (15-20 per hour), but this year the Moon (close to full) will be in the sky almost the whole night through.

Terry Oswalt was high in the Andes at Cerro Tololo Observatory when he took this stunning photograph of the Milky Way's center. Thirty minutes' exposure, a 50 mm lens stopped to *f/2.8 (to increase* sharpness), and 400 ASA *slide film* did the trick.



2 Pallas (0^h08^m, -0°08′ on the 15th) is a 9.7 magnitude object in Pisces and rises shortly before the Sun.

3 Juno can be found at 7^h41^m, +13°58′ at midmonth (when it is at 8.9 magnitude), and sets around midnight.

4 Vesta on the 15th is at 4^h08^m, 18°27′ and will set at about 10 p.m. local time. Its brightness is 8.1 magnitude.

Jupiter

Mars' companion in the heart of Leo, Jupiter is the most outstanding planet in the sky after Venus sets (around 10 p.m.). Moving slowly and steadily westward toward Regulus, which it will not quite overtake, Jupiter provides a magnificent sight — whether seen naked-eye, with binoculars, or through a telescope.

Jupiter's angular size on the 1st (when it will be 4.598 AUs, or 428 million miles, distant from us) spreads 43 seconds of arc across its equator and 40 seconds from pole to pole. By the end of the month, our distance from it will have increased to 462 million miles and its equatorial diameter will have shrunk to 39 arc-seconds.

As we mentioned on page 49 of the February 1980 *ASTRONOMY*, there'll be an unusual event taking place among the jovian moons on April 9th. Around 12:00 Universal Time (7 a.m. EST and 4 a.m. PST, same day), all four of the Galilean moons will be invisible, being either in eclipse, in transit over the disk, or occulted. The snag: the time of day when this happens is such that only the western half of North America is placed so as to see it before Jupiter sets. Take a look anyhow, because you've a 10-year wait until the next one (1990).

Saturn

Saturn, the dimmest member of the "Big Three" in Leo, is moving very slowly westward toward Jupiter, Mars, and Regulus. At magnitude +1.0, it won't look too different from an ordinary star, but all around it are only 4th and 5th magnitude stars so you should have little difficulty making out which object is Saturn: just compare the Star Dome with the sky.

A telescope (or even good binoculars) will reveal at least one of Saturn's moons to you. Titan is the brightest of them at magnitude 8.4 and will reach western elongation (separation) from the planet on the 5th and 21st of April; eastern elongations come on the 13th and 29th. Its angular distance will be about 10 Saturn-diameters.

With the rings' glare missing, telescope users should grab this opportunity to get a look at the other saturnian moons besides Titan: Rhea (10th magnitude) will be at eastern

Above: Comet Bradfield's motion shows clearly in 3 photos taken during a 2 hour period February 2. Photo by Ron Gattie. Right: Jiri Krakora caught 2 meteors during last December's Geminid shower just by pointing his camera at the pole and exposing for 25 minutes.

moon data

Last quarter: Apr. 8 at 12:08 UT in Sagittarius; new: Apr. 15 at 3:46 UT in Pisces; first quarter: Apr. 22 at 2:59 UT in Cancer; full: Apr. 30 at 7:35 UT in Virgo. Perigee: Apr. 14 at 7^h UT; apogee: Apr. 26 at 20^h UT.

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 UT on Jan. 2, then the time in EST would be 10 p.m. Jan. 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m. on March 4.

elongation on April 2, 6, 11, 15, 20, 24, and 29. Rhea's distance is about 4½ saturnian diameters.

Tethys (magnitude 10.6) has a 1.89 day orbital period and so elongations come fast and furious. The dates of each third eastern elongation are April 1, 7, 13, 18, 24, and 30. Tethys is close to Saturn, no more than around 2½ diameters separation at maximum.

Dione is a bit dimmer than Tethys — 10.7 magnitude — and its elongations go out to a little over 3 Saturn diameters. The dates of every other eastern elongation are: April 3, 8, 14, 19, 25, and 30.

Uranus

Libra, the "host-constellation" of Uranus, doesn't rise until about 11 p.m. (local time) at the start of the month, dropping back to 9 p.m. by month's end.

During April, Uranus moves west-northwest about a degree, and can be found all month long around 2° south of a flat triangle formed by Zeta (ζ) Librae (mag. 5.6), 34 Librae (mag. 5.9), and 32 Librae (mag. 5.9).

On the first, Uranus will be exactly 18 AUs from Earth, a distance of some 1.7 billion miles. At this time, it will present a little 3.8 arc-second diameter disk that may look stellar in small telescopes.

Neptune

Neptune is in eastern Ophiuchus, about 2° east and a bit south of 4.5 magnitude Xi (ξ) Ophiuchi. At the commencement of the month, Neptune is as far east as it will get until mid-December and is now moving westward back toward Xi.

The region rises around 1 a.m. at the beginning of the month and 2 hours earlier by the end. You'll find Neptune as a tiny, dim (mag. 7.7) blob, 2.4 seconds of arc in diameter.

Pluto

As anyone who's looked for it can tell you, Pluto's a bear to find. But now the job will come a bit easier, thanks to its fortuitous conjunction with a certain star, known somewhat cryptically as HR 5156.

HR 5156 is a magnitude 5.9 yellowish star in the southwest corner of Bootes (1950 coordinates: $13^h39^m45^s$, +8°38′28″). On this page you'll find a chart showing the starfield immediately around HR 5156 and the path Pluto is predicted to take. Closest approach will be on April 16. Finding the 13.7 magnitude dot that's Pluto crawling along should be easier with the help of the chart.

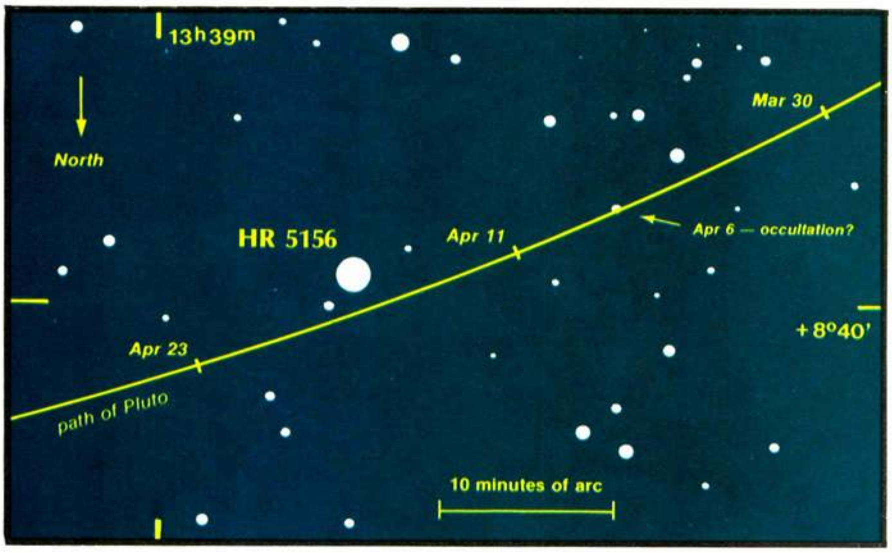
Opposition for Pluto happens on the 10th, just to the east of HR 5156, and a few days earlier on the 6th (at around 23 hours UT), there's a chance that Pluto or its moon Charon will occult an anonymous 12th magnitude star. 23 hours UT is 6 p.m. EST, when Pluto will be just rising for viewers on the eastern coast of North America. But as the sky won't fully dark then...well, to be honest, it's likely they're going to miss out. (And the occultation may not happen anyhow.)

Bear in mind that since Pluto is magnitude 13.7, any prospective viewers will need: 1) a dark site for viewing, and 2) a telescope at least 8″ in aperture. Optical quality being equal, the bigger the telescope the better.

Meteors

The major activity in April comes from the Lyrids, a medium to poor shower (10 per hour average) whose radiant point lies on the Lyra-Hercules border. The time of maximum activity comes this year on the night of the 21st-22nd when the Moon is in the sky at first quarter phase.

Pluto will be near to the star HR 5156 from April 10th to 20th; we've plotted this chart showing Pluto's path to help observers with medium to large telescopes find the elusive and dim object. (The epoch of the coordinates is 1950.)



april satellites of jupiter
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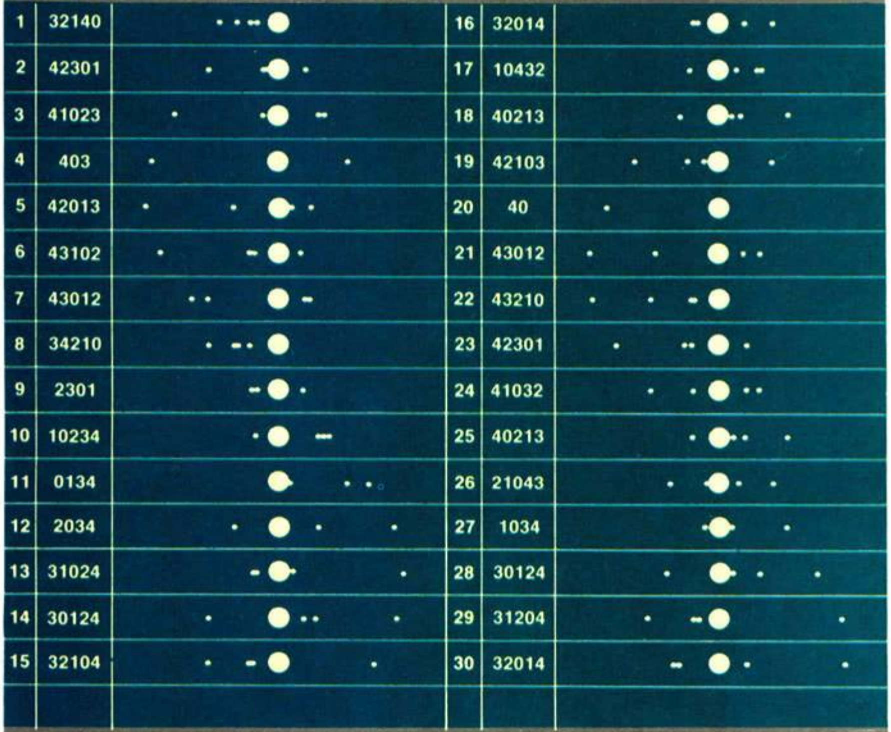
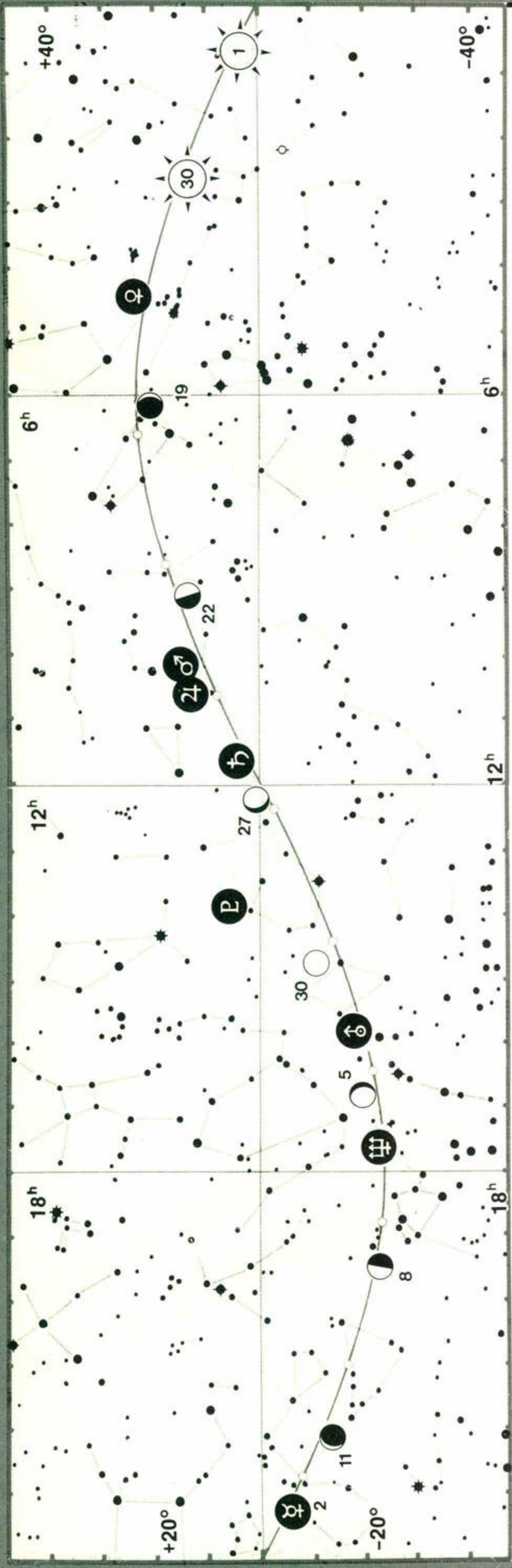


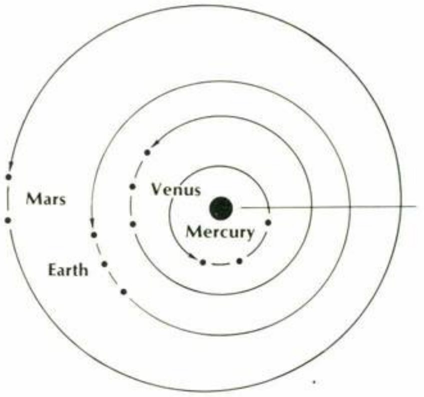
1	32140	16	32014
2	42301	17	10432
3	41023	18	40213
4	403	19	42103
5	42013	20	40
6	43102	21	43012
7	43012	22	43210
8	34210	23	42301
9	2301	24	41032
10	10234	25	40213
11	0134	26	21043
12	2034	27	1034
13	31024	28	30124
14	30124	29	31204
15	32104	30	32014

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope.)

Planet Finder April 1980

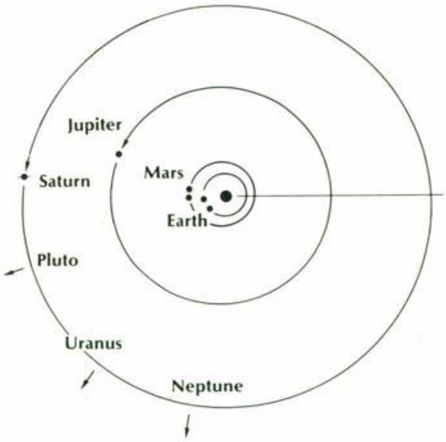

+40°
-40°
1
30
6h
19
6h
22
12h
27
12h
30
5
18h
8
18h
11
2
+20°
-20°

The Planets in Their Courses


Mars
Venus
Mercury
Earth

The positions of Mercury, Venus, Earth, and Mars in their orbits are shown for the beginning, middle, and end of the month. (Mars for the beginning and end only.) The vernal equinox is the line at right.

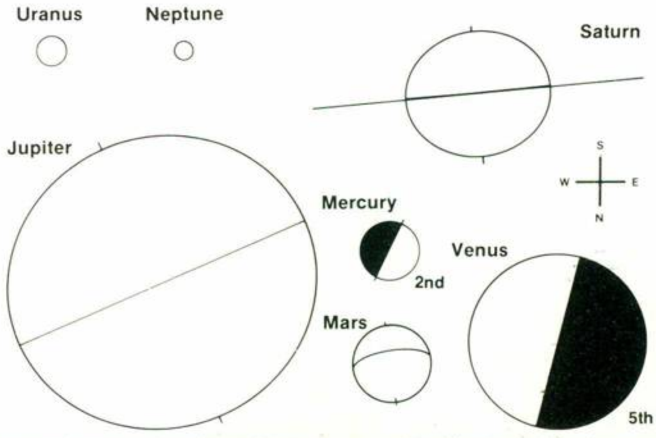
The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter and Saturn for midmonth. The outermost planets' directions are indicated.


Jupiter
Saturn
Mars
Earth
Pluto
Uranus
Neptune

Positional Data

Planet		Date	R.A. (1980.3)	Dec.	Mag.	Distance (AU) from	
						Earth	Sun
Mercury	☿	10	$23^h40.6^m$	−4°43.1′	+0.3	0.99	0.45
		20	$0^h33.6^m$	0°48.7′	−0.1	1.13	0.43
		30	$1^h36.7^m$	8°01.0′	−0.7	1.25	0.38
Venus	♀	10	$4^h13.7^m$	24°48.9′	−4.0	0.68	0.72
		30	$5^h27.3^m$	27°31.6′	−4.2	0.52	0.72
Mars	♂	15	$9^h57.9^m$	15°16.3′	0.0	0.89	1.65
Jupiter	♃	15	$10^h11.9^m$	12°30.2′	−1.9	4.76	5.40
Saturn	♄	15	$11^h32.0^m$	5°37.9′	+1.0	8.60	9.45
Uranus	⛢	15	$15^h29.7^m$	−18°40.1′	5.9	17.86	18.74
Neptune	♆	15	$17^h27.9^m$	−21°50.3′	7.6	29.73	30.28
Pluto	♇	15	$13^h39.9^m$	8°39.6′	13.8	29.20	30.16

Telescope View


Uranus
Neptune
Saturn
S
W
E
N
Jupiter
Mercury
2nd
Venus
Mars
5th

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gazer's
gazette

observing galaxies

by
F. Michael Witkoski

For most people, an evening of observing means a tour of the solar system with a couple of stellar and deep-sky objects thrown in. You might even spend your time just looking at the Moon and planets only — these are easily accessible with little more than a modest-size telescope and a clear sky.

In the typical suburban murk, this is about all you get. Going a few miles farther out will bring in some fainter objects, but even here you're observing only "the best and brightest." Light pollution deprives you of one of the best of nature's glories — the galaxies — to the point where (with just two or three exceptions) you almost forget about them entirely. Galaxies may be the most under-observed of all deep-sky objects.

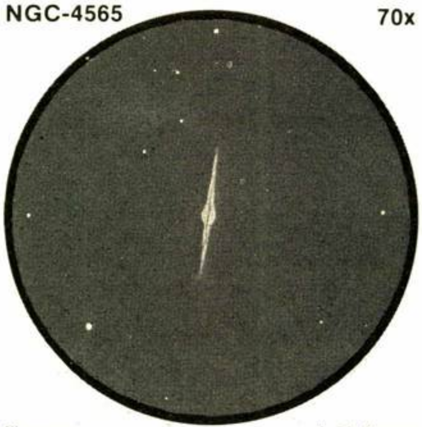
This can't be because they're scarce! Among the nearly 8000 *NGC* (*New General Catalogue*) entries, the majority are galaxies. The problem is that with few exceptions, they are relatively dim. While some clusters and nebulae contrast sharply with a less-than-adequate sky, most galaxies cannot — so you end up being content merely to find and identify only the brighter ones.

Galaxy observing requires perfect sky and atmospheric conditions. A clear moonless sky far from city lights is absolutely essential. Apart from these conditions, would-be galaxy observers need to be careful how they prepare themselves and their equipment: the usual slapdash approach which suffices for the Moon and planets will be fatal here. (For full details, see box on page 42.) Even slightly disregarding those prerequisites could make all the difference.

Neighboring Galaxies

Our nearest significant galactic neighbors are the Large and Small Magellanic Clouds, two small irregular galaxies about 200,000 light-years away. The nearest galaxy comparable to ours, M-31 in Andromeda, is about 2,200,000 light-years distant. Associated with M-31 and the Milky Way are about 20 smaller galaxies (including the Magellanic Clouds) which comprise our "Local Group." Farther outward, at about 10 million light-years from us, are the Ursa Major and Sculptor Groups, clusters similar to the Local Group. On even greater scales, clusters of galaxies of various sizes — including the relatively nearby, gigantic Virgo cluster of galaxies — appear to be distributed through space as far as our largest telescopes can see.

NGC-4565 **70x**



4" scope **J. Mullaney**

The Magellanic Clouds, unfortunately invisible from most of the Northern Hemisphere, are by far the most notable. Easily seen by the naked eye as small wispy cloudlets, they were first recorded in 1519 by the crew of the Portuguese explorer Ferdinand Magellan. Being nearby, the Clouds provide a wealth of observing pleasure. Literally thousands of their stars are resolvable, while dozens of their clusters and gas clouds can be seen and examined in great detail.

The premier northern hemisphere galaxy is M-31, a prominent feature of the autumn sky that is visible to the unaided eye on a dark night as an elongated patch of haze. Ten times farther from us than the Magellanic Clouds, M-31 does not reveal as much detail despite its much greater intrinsic size. However, it has a distinctive spiral pattern which becomes apparent with moderate optical aid. For the user of a 6-inch or larger telescope, a spectacular bright nucleus, tremendous starclouds at the edges, and a hint of dark lanes in the spiral arms all await.

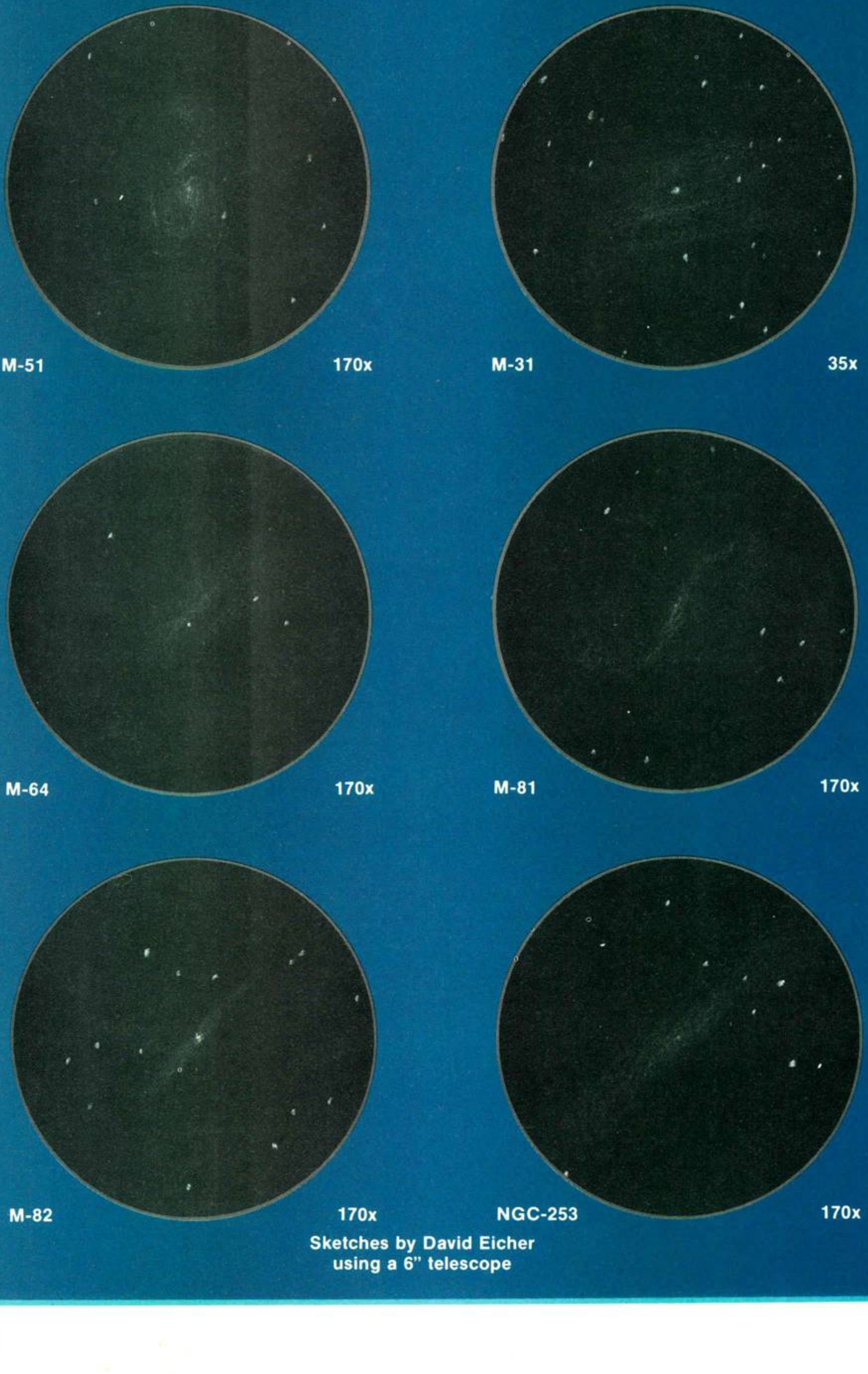
M-31 possesses four elliptical satellites visible through amateur telescopes. These are M-32, NGC-205, NGC-185, and NGC-147. M-32 and NGC-205 lie in the same low power field with M-31, although you'll see absolutely no detail. M-32, at magnitude 9.5, is immediately south, while NGC-205, at magnitude 10.1, lies to the northwest.

NGC-185 and NGC-147 are both much fainter, magnitudes 11.8 and 12.1 respectively, and require perfect observing conditions (M-31, M-32, and NGC-205 can stand less than ideal skies). Even so, their low surface brightness allows very little contrast and both, particularly NGC-147, are nearly undetectable through a small telescope. This pair resides about 7° north of M-31, just across the border into Cassiopeia.

Another Local Group member is M-33, a fine face-on spiral in the otherwise dull autumn constellation Triangulum. Its published magnitude, 6.5, is very deceiving since M-33 is quite spread out and has no bright nucleus. The lowest possible power works best for observing M-33 — in fact a good pair of binoculars often gives you a better view than a telescope. Some observers claim to have seen this object without optical aid at all.

Although near to us, at 2.4 million light-years, M-33 is quite difficult; finding it represents a milestone to the

the soft glow of the galaxies



M-51 170x

M-31 35x

M-64 170x

M-81 170x

M-82 170x

NGC-253 170x

Sketches by David Eicher
using a 6" telescope

beginner and pleasant reassurance for the experienced observer.

Springtime

By far the most favorable season for galaxy observing is spring. The western end of Virgo, Coma Berenices, Canes Venatici, Leo, and Ursa Major house the largest sampling and contain the majority of galaxies with "M" (Messier) numbers.

The most extensive collection available is the Virgo Cluster, also known as the "Realm of Galaxies" or the "Field of the Nebulae." Centered about 10° east of Denebola, the tail star in Leo, and a bit south of the Virgo-Coma Berenices border, this family contains at least 2500 galaxies. The brightest centralized members are M-85, M-88, M-98, M-99, and M-100 in Coma, and M-58, M-59, M-60, M-84, M-86, M-87, M-89, and M-90 in Virgo. All can be seen through a small telescope, although no details will show.

A tour through this region might start at the fifth magnitude star 6 Comae, 6° east of Denebola. Clustered around it are three spirals, M-98 and M-99, 1° respectively to the west and southeast, and M-100, 2° northeast. A quick trip 3° north-northeast from M-100 brings you to M-85, a nice elliptical. Returning to M-99 and proceeding due east 3°, you'll find the spiral M-88. Head south 2°, crossing into Virgo, and you see M-87, an immense elliptical which is the gravitational hub of the cluster. Often photographed and intensely studied, this huge stellar repository, although seen as only a blob of light through most telescopes, may hold a key to astronomical understanding of how galaxies evolve.

From M-87 you can either veer 1° northwest to the pair M-84 and M-86, or follow a chain starting 2° northeast at M-90 and passing through M-89, M-58, M-59, and M-60 to complete the basic tour of this exceptional area. An easy way to learn this route is to trace it out on an atlas several times prior to an observing session. Afterward it will seem as familiar as the way to your grocery store.

M-49, M-61, and M-104, all south of the main portion of the cluster, round out its Messier membership. M-49 is a nice elliptical and M-61 is a fine face-on spiral, but the prime galaxy here from the observer's point of view is M-104.

Known also as the Sombrero Nebula, it's a striking edge-on galaxy located just north of the Virgo-Corvus border. Relatively isolated, which enhances its prominence, it glows at magnitude 8.2, far outshining all other cluster members. Its best-known feature is the dark lane seen in photographs, but not always visible through a small telescope. Save this one for a perfect night!

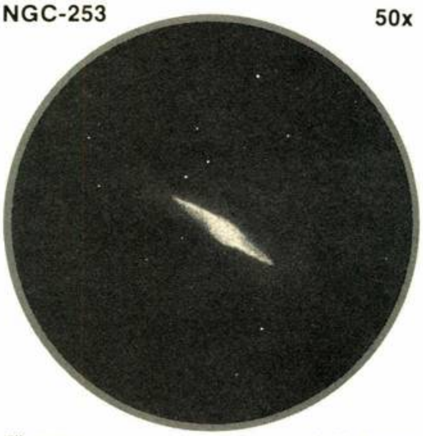
Numerous non-Messier galaxies belonging to the cluster are also visible using modest equipment. Through a wide-angle eyepiece many fields of view will contain several galaxies, and to avoid confusion, you'll find it's best to use a detailed atlas when exploring this region.

Other notable galaxies in Coma Berenices are M-64, the Black-Eye Galaxy, NGC-4565, a very well-known edge-on spiral, and NGC-4559, another spiral which is often overlooked.

Coma Berenices also houses a great cluster of galaxies, but because it's at ten times the distance of the Virgo cluster, it has only two members visible without a large telescope. These are NGC-4874 and NGC-4889.

The eastern end of Virgo, although not nearly as rich as the western end, hosts several galaxies bright enough for an 8-inch instrument. One handy reference point is the globular cluster M-5 in Serpens. Sweep west 4°, then 4° more, and you will encounter the 5th magnitude stars 110 and 109 Virginis.

NGC-253 **50x**



6" scope **J. Mullaney**

Clustered around 110 Vir are no fewer than eight galaxies, most of which unfortunately are difficult though not impossible. Immediately west of 109 Vir is NGC-5746 and a dim companion, NGC-5740; this is a moderately challenging duo. There are easy pathways to other galaxies in this region.

Canes Venatici, south of Ursa Major, is rather devoid of bright stars but wealthy in galaxies. Four of Messier's entries, M-51, M-63, M-94, and M-106 (all spirals), are included.

One of the most celebrated of these galaxies is M-51, the Whirlpool Nebula. Located a few degrees south of the handle of the Big Dipper, it is composed of a main body — a well-defined, face-on spiral — and a satellite joined by a radiant stream of stars.

The main component was first seen to have spiral arms by William Parsons (Lord Rosse), a mid-nineteenth century Irish nobleman whose 72-inch telescope was the largest in the world at the time. Of course, the true nature of this and other galactic systems was a complete mystery at that time, but over the succeeding several decades, larger and more sensitive instruments helped unravel the secrets of the cosmos. As a result, today's casual observer far better appreciates what he sees as he peers at the wonders of the sky.

M-63, M-94, M-106, and NGC-4631, an unusual edge-on, cannot match M-51's uniqueness, but are all very worthwhile for the observer with a small telescope and far exceed most of Canes Venatici's remaining galaxies.

Within the borders of Leo lie several impressive small groups of galaxies and some fine singles:

The foremost group, 3° south-southeast of Theta (θ) Leonis, contains M-65 and M-66, a close pair of angled spirals bright enough for a 3-inch telescope. Just north is NGC-3628, slightly dimmer and seen edge-on.

M-95, M-96, and M-105 form another attractive trio, one which lies midway and 3° south of a line from Theta Leonis to Regulus (Alpha [α] Leonis). M-95 and M-96, face-on spirals about 1° apart, do not quite equal M-65 and M-66 but still are within range of a small instrument, as is M-105, just north.

Through an 8-inch, two companions to M-105 come into view. They are NGC-3384 and NGC-3389. At magnitude 12.2, NGC-3389 is quite difficult, but when visible, forms an elegant triangle with its two brighter companions. Try for it during your next observing night.

Leo's finest single galaxy, NGC-2903, is a fairly bright (9.7 magnitude) face-on spiral 1½° south of the naked-eye star Lambda (λ) Leonis at the western extremity of the constellation. A noteworthy single in the southern part of Leo, far removed from the Lion's main body, is NGC-3521.

Altogether 66 galaxies of magnitude 13.0 and brighter reside in Leo. How many can you find?

Ursa Major is quite rich in galaxies, housing five Messier galaxies among its 108 members at magnitude 13.0 and brighter.

M-81, a splendid spiral, and M-82, an irregular which until recently was thought to be exploding, dominate the constellation as well as the previously mentioned Ursa Major Cluster. At magnitudes 8.0 and 9.2, they are among the most accessible galaxies in the sky. Northwest of the Big Dipper, near the star 24 Ursae Majoris, this pair is easily visible through so modest an instrument as a

2.4-inch refractor or even a good pair of binoculars.

Other members of the Ursa Major Cluster visible through amateur instruments are NGC-2976, NGC-2985, and NGC-3077. All are of about 11th magnitude and lie within a few degrees of M-81 and M-82.

The remaining Messier galaxies in Ursa Major are the three spirals M-101, 7° east of Zeta (ζ) Ursae Majoris, M-108, 1° southeast of Beta (β), and M-109, ½° south of Gamma (γ).

M-101 at magnitude 9.0 is a nice face-on whose spiral arms are partially visible through an 8-inch on a crystal clear night. Unfortunately, this galaxy is spread out, and like M-33, is hard to detect unless sky conditions are perfect. M-108 and M-109 are more compact and consequently brighter and easier than M-101.

Ursa Major is endowed with several other easily observed galaxies. Some, for example NGC-3184 and NGC-3953, are close enough to a bright star to be found instantly, but you'll find most are best located using a detailed atlas.

A spectacular spiral in Hydra, M-83, is the final Messier galaxy of the spring. At magnitude 8.0, this specimen stands in isolated splendor; however, because it's close to the horizon, many northern observers often overlook it.

Further south, in Centaurus, is a bright peculiar system, NGC-5128, an elliptical with a large dark band. At magnitude 7.2, this is one of the sky's outstanding galaxies, though not easily seen from much of the United States.

Late spring skies bring the galaxy hunter's bonanza to an abrupt end. The few items available for inspection are small and faint, showing no detail through a nonprofessional-size instrument. However, any jaded observer seeking a challenge has some opportunity here.

For example, 1° north-northeast of M-13 (the Great Hercules Globular Cluster) lies a small spiral galaxy, NGC-6207. This 12.3 magnitude object manifests itself only as a faint smear of light and is as dim an object as can be seen through a 6-inch telescope.

Interesting and thought-provoking is its contrast with the Great Cluster, one of the marvels of the night sky as seen from Earth. The key phrase is "as seen from Earth," because if you could place these objects at equal distances, NGC-6207 would shine by far the brighter, and if the two could exchange places, NGC-6207 would overpower the brightest stars in the sky (as we see them), while M-13 would shrivel to invisibility.

Summer, Fall, and Winter

The summer and winter skies feature very few galaxies, due to the thickness of the Milky Way during those seasons, and even though fall

galaxies for medium-size telescopes

NGC #	Other	Const.	R.A. (1975)	Dec.	Type*	Size	Mag
55		Scl	$00^h 13.8^m$	-39°22′	S	2.5 x 4′	7.8
147		Cas	00 31.9	48 22	E	6.5 x 3.8	12.1
185		Cas	00 37.6	48 12	E	3.5 x 2.8	11.8
205		And	00 39.0	41 33	E	8.0 x 3.0	10.1
221	M-32	And	00 41.4	40 44	E	3.6 x 3.1	9.5
224	M-31	And	00 41.4	41 08	S	160 x 40	5.0
253		Scl	00 46.3	-25 26	S	22 x 6.0	7.0
292	S Mag C	Tuc	00 51.9	-72 58	I	216 x 216	1.5
598	M-33	Tri	01 32.5	30 32	S	60 x 40	6.5
628	M-74	Psc	01 35.3	15 40	S	9.0 x 9.0	11.0
891		And	02 21.0	42 14	S	12 x 1.0	12.2
1068	M-77	Cet	02 41.4	-00 08	S	2.5 x 1.7	10.0
1316		For	03 21.6	-37 20	S	3.5 x 2.5	10.1
	L Mag C	Dor	05 26.0	-69 00	I	432 x 432	0.5
2403		Cam	07 34.4	65 40	S	16 x 10	8.8
2903		Leo	09 30.7	21 36	S	11 x 4.7	9.7
2976		UMa	09 45.3	68 02	S/I	3.4 x 1.3	10.8
2985		UMa	09 48.1	72 24	S	4.0 x 3.0	11.3
3031	M-81	UMa	09 53.6	69 11	S	18 x 10	8.0
3034	M-82	UMa	09 53.8	69 48	I	8.0 x 3.0	9.2
3077		UMa	10 01.4	68 52	E/I	2.6 x 1.9	11.0
3115		Sex	10 04.0	-07 35	E/S	4.0 x 1.0	10.0
3184		UMa	10 16.8	41 33	S	5.5 x 5.5	10.5
3226		Leo	10 22.1	20 01	E	1.0 x 0.9	12.7
3227		Leo	10 22.2	19 59	S	3.0 x 1.2	11.6
3351	M-95	Leo	10 42.6	11 50	S	4.0 x 3.0	11.0
3362	M-96	Leo	10 45.4	11 57	S	6.0 x 4.0	10.2
3379	M-105	Leo	10 46.5	12 43	E	2.1 x 2.0	10.6
3384		Leo	10 46.9	12 46	E/S	4.0 x 2.0	11.0
3389		Leo	10 47.1	12 40	S	2.2 x 1.0	12.2
3521		Leo	11 04.6	00 06	S	6.0 x 4.0	10.2
3556	M-108	UMa	11 10.1	55 49	S	7.8 x 1.4	10.8
3623	M-65	Leo	11 17.6	13 14	S	7.8 x 1.6	10.3
3627	M-66	Leo	11 18.9	13 08	S	8.0 x 2.5	9.7
3628		Leo	11 19.0	13 44	S	12 x 2.0	10.3
3953		UMa	11 52.5	52 28	S	6.0 x 2.8	11.1
3992	M-109	UMa	11 56.3	53 31	S	6.4 x 3.5	10.9
4027		Crv	11 58.3	-19 07	S	2.0 x 1.7	11.6
4038		Crv	12 00.6	-18 43	S	2.5 x 2.5	11.0
4198	M-98	Com	12 12.6	15 03	S	2.2 x 2.0	11.0
4254	M-99	Com	12 17.7	14 43	S	4.5 x 4.0	10.4
4258	M-106	CVn	12 17.7	47 27	S	20 x 6.5	9.0
4303	M-61	Vir	12 20.7	04 37	S	5.7 x 5.5	10.2
4321	M-100	Com	12 21.7	15 58	S	5.2 x 5.0	10.4
4374	M-84	Vir	12 23.8	13 02	E	2.0 x 1.2	10.5
4382	M-85	Com	12 24.2	18 20	E/S	3.0 x 2.0	10.5
4406	M-86	Vir	12 25.0	13 05	E	3.0 x 2.0	10.5
4472	M-49	Vir	12 28.5	08 09	E	4.0 x 3.4	10.1
4426	M-87	Vir	12 29.6	12 32	E	3.0 x 3.0	10.1
4501	M-88	Com	12 30.8	14 34	S	5.7 x 2.5	10.5
4552	M-89	Vir	12 34.4	12 42	E	2.0 x 2.0	11.0
4559		Com	12 34.7	28 06	S	10 x 3.0	10.5
4565		Com	12 35.1	26 08	S	15 x 1.1	10.5
4569	M-90	Vir	12 35.6	13 18	S	7.0 x 2.5	11.1
4579	M-58	Vir	12 36.5	11 58	S	4.0 x 3.5	10.5
4594	M-104	Vir	12 38.6	-11 29	S	7.0 x 1.5	8.2
4621	M-59	Vir	12 40.8	11 47	E	2.0 x 1.5	11.0
4631		CVn	12 40.9	32 41	S/I	13 x 1.2	9.7
4649	M-60	Vir	12 42.4	11 42	E	3.0 x 2.5	10.0
4736	M-94	CVn	12 49.7	41 16	S	5.0 x 3.5	8.9
4826	M-64	Com	12 55.5	21 49	S	7.5 x 3.5	8.6
4874		Com	12 58.4	28 06	S	1.0 x 1.0	13.5
4889		Com	12 58.9	28 07	E	1.0 x 0.6	13.2
5055	M-63	CVn	13 14.7	42 10	S	9.0 x 4.0	9.8
5128		Cen	13 23.8	-42 53	E/I	10 x 8	7.2
5194	M-51	CVn	13 28.9	47 19	S	10 x 5.5	8.7
5195		CVn	13 28.9	47 19	I	2.0 x 1.5	11.0
5236	M-83	Hya	13 35.7	-29 44	S	10 x 8	8.0
5363		Vir	13 54.9	05 23	I/E	1.7 x 1.5	11.1
5364		Vir	13 55.0	05 09	S	5.0 x 4.0	11.5
5457	M-101	UMa	14 02.4	54 29	S	22 x 20	9.0
5740		Vir	14 43.2	01 47	S	2.5 x 1.5	12.6
5746		Vir	14 43.7	01 55	S	6.5 x 0.8	11.7
5846		Vir	15 05.2	01 42	E	1.0 x 1.0	11.5
6207		Her	16 42.2	36 53	S	2.0 x 1.0	12.3
7331		Peg	22 35.9	34 18	S	10 x 2.3	9.7
7793		Scl	23 56.6	-32 43	S	6.0 x 4.0	9.7

***Types: S stands for spiral, E for elliptical, and I for irregular.**

David Eicher | tricks of the deep-sky trade

The ability to see features in galaxies depends as much on seeing conditions and observing techniques as it does on aperture. Therefore, when you attempt to observe galactic details, don't just charge in. Wait for dark, clear, and moonless nights when the seeing is above average and make yourself as proficient as you can in a few simple but effective observing techniques.

Seeing conditions are the key. You need the ability to judge a given night's value for observing. This takes experience, but try a few short cuts. For example, on a night of average seeing, the Andromeda Galaxy (M-31) can be seen in an average telescope as a large, pale, fuzzy patch of light with its two dim companions close by. Under similar conditions, Messier 51 in Canes Venatici looks like two fuzzy patches of misty light in contact. But on a night of excellent seeing, M-31 can show a huge oval of bright nebulosity boasting two dark lanes and a massive spiral structure, while M-51 will display its beautiful spiral pattern with a dim bridge of nebulosity connecting it with NGC-5195 (its companion), and a foreground star projected upon its surface. Use these or your own test object(s) to assess quickly the quality of the night.

Getting your eye dark-adapted is very important for seeing subtle details in galaxies. When your eyes are in the dark for a few minutes, they increase their sensitivity to light. If you're trying to spot nebulosity on the limit of visibility, you *have* to take the time do this. Ideally, you should be out in the dark for an hour or so before starting observations.

A good "warm-up" plan is to look at less demanding objects such as globular or open clusters. Meteor observing is one interesting way to relax and ready your eyes. It is also good to keep your telescope outside while you are adapting your eyes so it comes to temperature.

When conditions are good, your telescope's ready, and you're fully dark-adapted, you must know exactly where to look and what to look for. If you are trying to spot the stellar nucleus of M-31, the bridge between M-51 and NGC-5195, the dark lane bisecting the Sombrero (M-104), or the spirality of M-101, you only need to know where the galaxy itself is. But if you are looking for a gaseous nebula, open cluster, or starcloud, you must know where that detail is.

A good way is to study a long exposure photograph of the galaxy in question. Memorize the bright stars and their positions in relation to the galaxy and the feature you wish to study. Once you have located the detail, you are only halfway there: you then need to know which of the various power eyepieces you want.

Experiment with different magnifications to see which is most beneficial. Extensive spiral arms might come up best in a low power ocular yielding a wide field of view. On the other hand, for a compact stellar nucleus, try high powers. Remember, the higher the magnification, the greater contrast the object will have against the background, but the fainter and fuzzier the image.

Averted vision is another valuable deep-sky skill. Looking at a faint object with the periphery of your eye means you spot more than when you look at it directly. For galaxies, this is a wonderful aid and in many cases a detail — dark lane, patch, gas cloud, spiral arm — can only be seen with averted vision.

Be careful, however, to discriminate between what you actually see and what you expect to see. When using averted vision, it's wise to compare carefully your view of the detail when using both averted and direct vision.

Field sweeping is another valuable technique for catching details, especially with a large object such as M-31, M-33, or NGC-253. It's easy to see detail in an object when it first "pops" into view. When you are fully dark-adapted, an object like a star cloud can be picked up much faster and easier if you sweep the field.

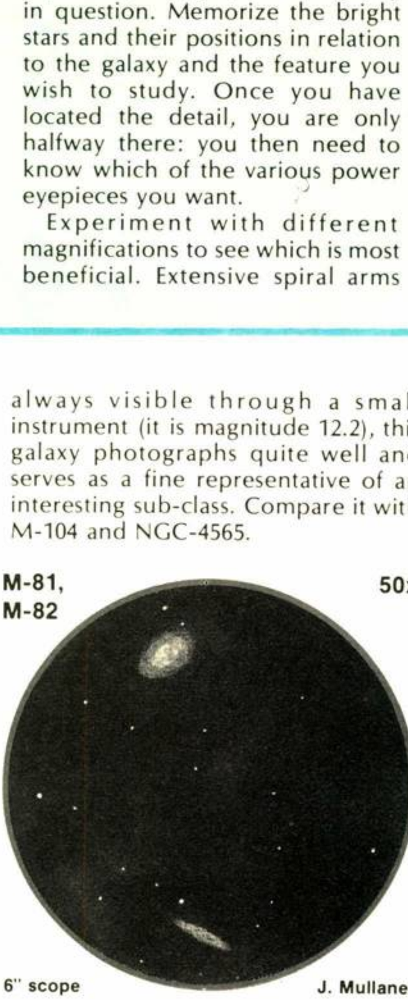
Keep your eye centered on the opposite side of the field as you sweep. In this manner, you use averted vision on new objects as they enter the eyepiece field, and you'll spot them easier.

skies are devoid of gas, dust, and dense star fields, great numbers of galaxies simply are not available. (The best known fall samples are, of course, M-31, M-32, and M-33.) The only other Messier galaxies in this part of the sky are M-74, a rather difficult spiral in Pisces, and M-77, a much easier spiral centered among a retinue of fainter counterparts in eastern Cetus.

The Sculptor Group, low on the southern horizon as seen from the United States, hosts the fine spiral NGC-253. Accompanied by several relatively dim companions, NGC-253, at magnitude 7.0, is exceeded in brightness and observability by only M-31 and the Magellanic Clouds.

For our last stop, let's return to Andromeda to visit NGC-891, a perfect edge-on spiral midway between bright Gamma (γ) Andromedae and M-34, an open cluster in Perseus. Although not always visible through a small instrument (it is magnitude 12.2), this galaxy photographs quite well and serves as a fine representative of an interesting sub-class. Compare it with M-104 and NGC-4565.

M-81, M-82 **50x**



6" scope **J. Mullaney**

This tour of the galaxies certainly isn't meant to be complete. The brighter objects have been emphasized, but there is no reason not to explore further since the possibilities are virtually boundless.

If you own an 8 to 12-inch telescope, the challenge seems particularly inviting. Even during the "off-season" there are hundreds of galaxies — although most are quite difficult — awaiting your inspection. As long as the skies are dark, clear, and the lights are off, the rewards are practically limitless.

Mike Witkoski has been observing the skies casually for a long time, but says he's gotten really serious about it only in the last few years. One of his ambitions is sighting all the NGC objects within reach of his 8" telescope. In the July 1979 issue he told about observing globular clusters.

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The optically flat substrate is coated with an evaporated inconel alloy that produces a 1.5 optical density mirror-like surface. A BK-7 optical window is used as the substrate due to its unusually good optical properties (Bubble Chamber Window material).

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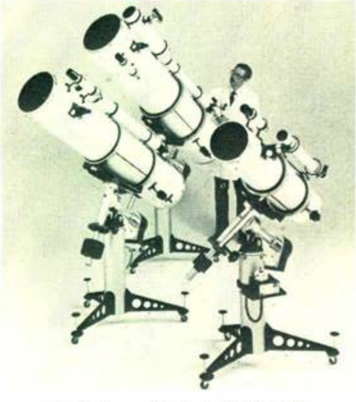

Meade Research Series 8,″ 10,″ 12½″

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The design of our new Nebulae Filter was built on the idea of what a nebula filter was originally conceived to do. Our New Nebulae Filter is setting new standards in the Nebula filter industry with its Ultra-Narrow transmission windows creating a much darker sky than was previously possible. This was accomplished while maintaining extremely high transmission of Nebular light (H-alpha, H-beta, Doubly Ionized Oxygen–OIII and Singly Ionized Nitrogen–NII). Since most cities are converting to High Pressure Sodium and Deluxe Mercury Vapor streetlights with broad transmission lines we took special care during the designing process to block these sky polluting lines. To reduce film fogging during astrophotography even in the country our filters essentially eliminate Natural Sky Glow caused by OI emissions. Our new filters are fabricated by using an all Dielectric approach to achieve the required Fast Rise Time, Narrow Bandwidth, Uniform Nebular Light Transmission, Significant Reduction of Stellar Scintillation and Large Integrated Blocking Ratio (Contrast or Signal to Noise). The coatings are sandwiched between two optically flat substrates and hermetically sealed and edge protected by two anodized rings; this more than doubles the life of a standard filter. To complement this we bond the filter into a black anodized cell, threaded for standard 1¼″ oculars.

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The characteristics of this filter makes it very useful for viewing only the visible component of nebulae light (H-beta & Oxygen), while blocking H-alpha, since the eye is not very sensitive to red light when dark adapted. This is a great visual only filter because of its wide Bluish Green bandwidth and deep blockage outside the transmission window.

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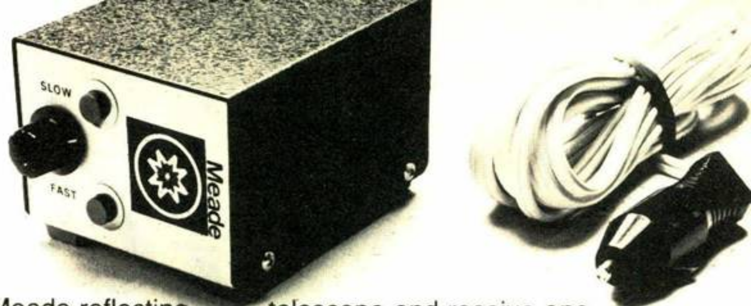

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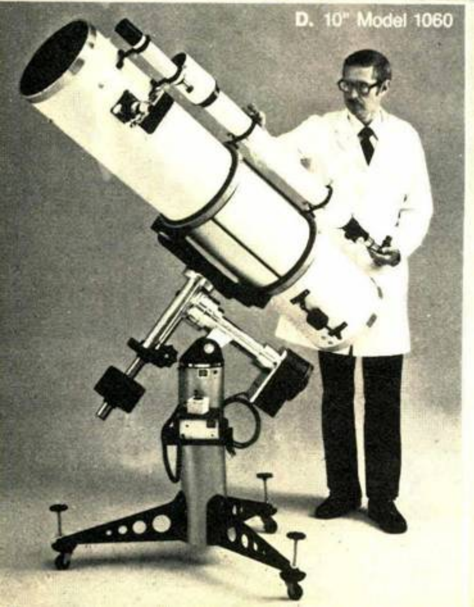
D. 10" Model 1060

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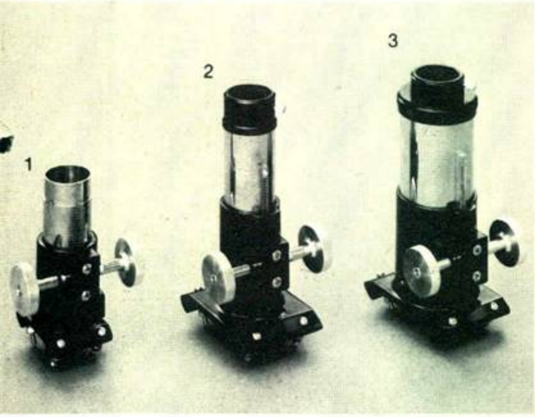

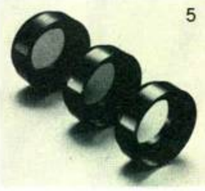

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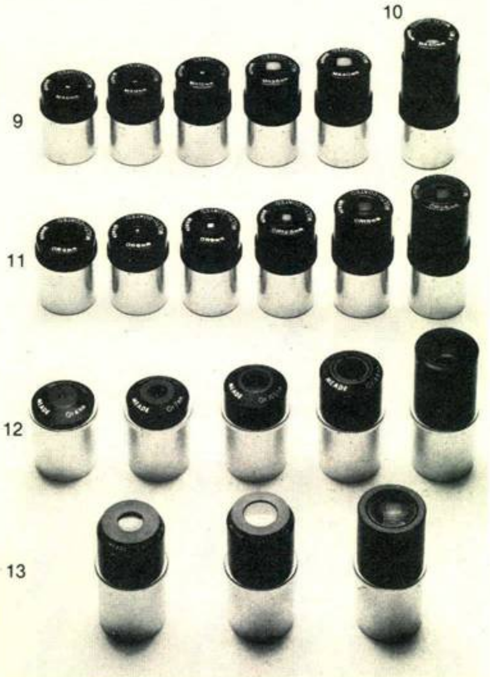

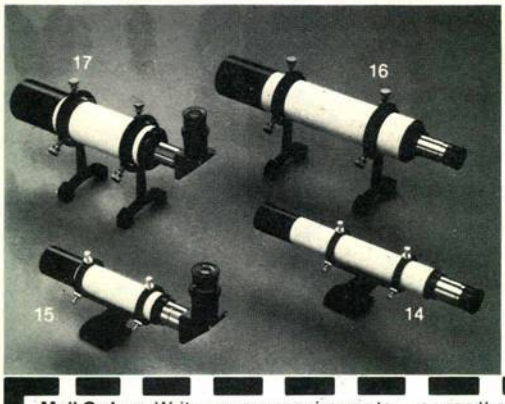

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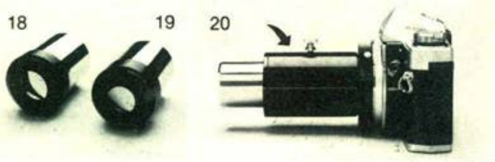

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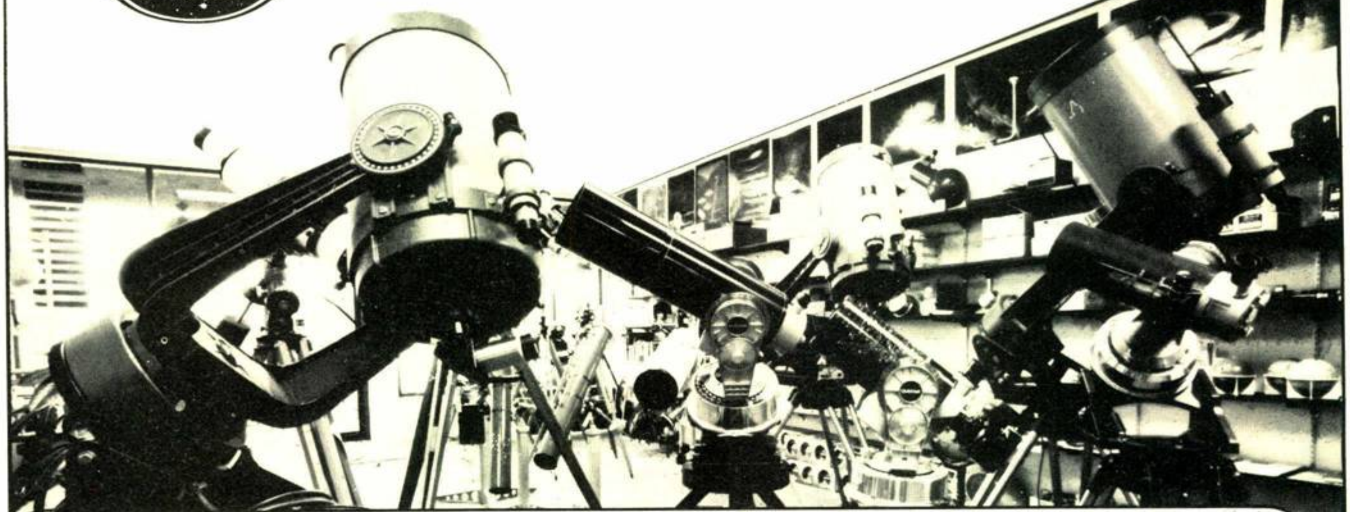

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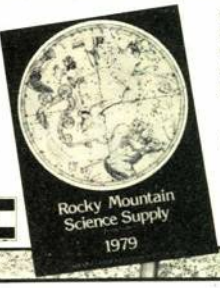

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This photograph of our Moon was taken through a Quantum Four under fair seeing (steadiness) conditions using a photo Barlow lens and H & W VTE film. It shows the Hyginus-Triesnecker area including the craters Manilius (bottom left), Agrippa, and Godon. Part of the magnificant Ariadeus Rill comes in from the left toward Hyginus, and the craterlet chain nature of the Hyginus Cleft can be discerned clearly. The resolution recorded on the original negative is 1 to 1½ arc seconds, but unavoidable losses in printing and reproduction have removed the very finest details plainly visible thereon. Even the best photographic image falls short of revealing what the eye would have seen at that moment.

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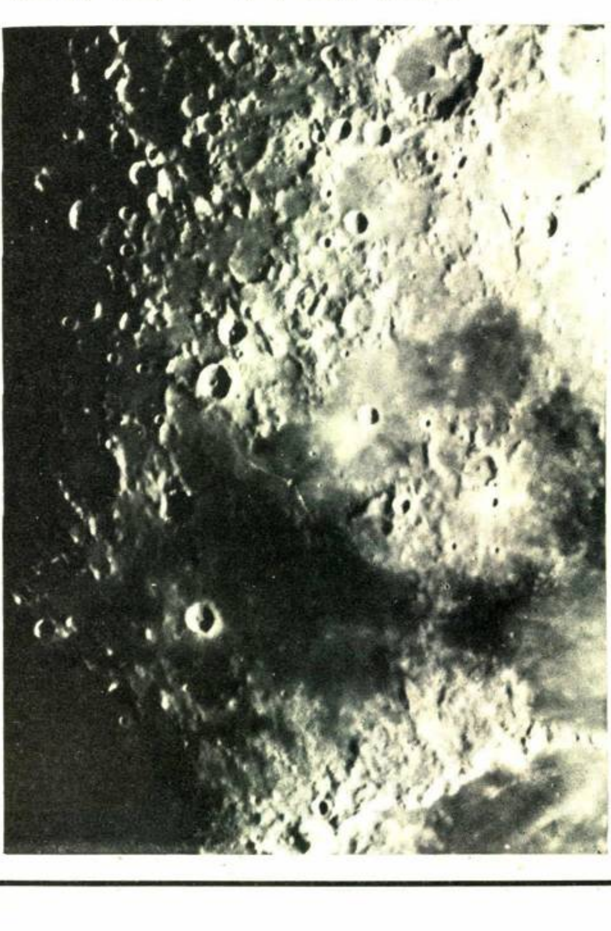

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what accessories do you really need?

equipment atlas

by Ken Fulton

I can almost see you.

You are standing before a mailbox, holding an envelope. For the twentieth time you check to make sure the envelope is stamped, correctly addressed, and sealed. Your heart is pounding like a kettle drum. Beads of perspiration glisten wetly upon your forehead.

Suddenly, you move the envelope toward the slot, but then you hesitate. For a second, you wonder if you've made the right decision. Wouldn't geology be much less expensive?

But then, you think back a bit. You've done your homework. You've studied the articles in ASTRONOMY, the various books available in the public library. You've almost memorized the ads and catalogs. You've weathered the price increases. Your inquiring letters to the manufacturers and/or dealers were answered by human beings, not computers.

Finally, after much soul-searching, you've selected a telescope that you, your wallet, and your back can all live with. You've carefully filled out the order form, correctly computed the total cost of the telescope including packing and crating charges. You've checked and rechecked the shipping address on the order form — each and every word and number is correct, including the zip code. You've even added your phone number, just in case.

So go ahead. It's time. Mail it.

There! It's done. You just ordered your first telescope. Congratulations!

Now for a few predictions based not on the gift of prophecy, but on twenty years experience as an active astronomy enthusiast:

From this day forth until delivery, worry will nibble away at your sanity morning, noon, and night. If you just stand there and wait, you'll go bananas in 6.23 days. Unless you occupy your mind during this agonizing waiting period (which can run into months!), your nerves will be worth about the same as a 10" f/4 richest field mirror used as a moon hubcap on a '51 Chevy pickup.

Take my word for it. When the instrument finally arrives, chances are you will be well pleased and ready for clear, dark skies. During the next three weeks of the first monsoon rains your location has ever recorded, you will dust, adjust, align, re-align, and admire that precision eye, listen to the rhythm of the falling rain, hum the soundtrack to *Star Trek*, and calm down a bit. For hours and hours, you will simply sit and stare at the culmination of your dreams. For a while your life will be complete.

For a while...

Ah, but not forever. Like the call of the wild, accessories will start whispering to you, irresistibly seductive.

Oh yes, they will! And you will hear. You will listen. For like dust on a primary mirror, it is inevitable.

From the ads, from the catalogs, eyepieces, various filters, astrocameras, special films, guide telescopes, richest field finders, drive correctors, gargantuan star atlases, door-stopper textbooks, slow-motion controls, image intensifiers — even observatory domes — all will beckon.

You will try to ignore their hypnotic calls. But ever so soon, you will find yourself (only to pass the time, of course) making a short list of just the "must have" extras. When you've finished, if you run true to average, the cost of these extras will add up to a shade more than the amount you will make during the next three years, before taxes.

Your list of desired eyepieces alone will be a veritable zoo of classy glass gems, medium-priced multicoats, loanable cheapies, and some "slightly worn" war-surplus Erfles. And after this, you might find yourself checking real estate ads for a used but clean mountain top...

What should you do, now that you've got Accessory Fever?

First: Come back down to Earth. It may be a cruel thing to say, but it's for your own good. There is no cure for the Fever. You *will* want all of those wonderful optional accessories, maybe even two of each. What now remains to be seen is whether you will hock everything you own just to be accessory-rich or whether you'll use common sense and slowly — but surely — purchase each item at the proper time.

But watch out: In your delirium, you'll come up with some great — even fantastic — excuses. I can hear 'em now:

1. "I Need Every Star Atlas in Print, Because They're There!"

Horsefeathers! (That's tough talk.)

If you aren't thoroughly familiar with the use of a simplified star chart like the Star Dome, then it's foolish to be yearning for a more advanced atlas like the excellent *Norton's Star Atlas*. When you feel comfortable with the chart in Star Dome during actual observing sessions, then by all means go purchase *Norton's*.

Likewise, until you have mastered

Norton's, you have no need of the *Skalnate Pleso Deluxe Atlas of the Heavens*. (Yes, I know it's beautiful!) Consequently, there is little call to order Vehrenberg's comprehensive *Photographic Star Atlas* unless you are very proficient in the use of the *Skalnate Pleso Atlas*.

You follow? All of these printed aids are fine and necessary tools of astronomy, but each one should be purchased in the proper sequence. The same goes for astronomy textbooks, guides, technical manuals, conference reports, advanced reference books, and the like.

2. "I've Got to Have a Larger Finder. Mine is Useless for Serious Work."

Serious work, huh? Come on, snap out of it! Try to remember that you've just received your first telescope, not a research grant. Don't let your head swell to such proportions that you'll need a counterweight just to walk straight. Counterweights aren't cheap, you know. And remember, you've got the Fever.

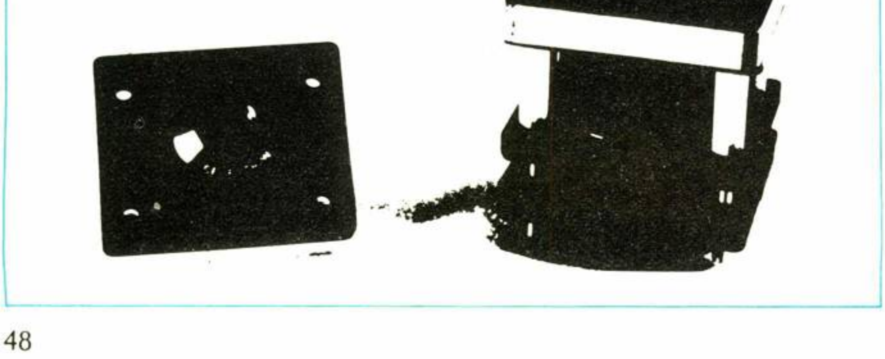
For a while, at least, try to forget the words "serious" and "work" and just concentrate on enjoying your telescope. There is no law that says you can't have a little fun with it. Honest! And as for that small, "useless" finder, have you *really* given it a chance? Bear in mind that some very experienced observers prefer zero power finders.

Unless you know the night sky well, a modest, low-power finder is the best type to cut your teeth on. It will help your eye just enough, but won't overpower and confuse it with a plethora of new stars. At first, it can be very confusing to aim the telescope in the general direction of the celestial object you're seeking only to peek through that large finder and see fifty stars where your naked eye saw five.

To make matters worse, that key star on the chart you planned to use as your crucial "stepping-stone-and-get-my-bearings" star is now lost amid forty-nine other fiery gems. Right off, you'll begin to hyperventilate and scream. And, as every experienced observer knows, doing this near a telescope immediately fogs the mirror, turns the seeing bad, and attracts night-raider ants to attack your midnight snack.

The whole thing is complicated even more if the finder is an elbow or right-angle type. Then your sense of direction can really go down the tubes because you are looking down, the telescope is looking up, and everything is reversed. Weird things happen. In your search you may get a red out-of-focus glow that you just know is either Mars or a red giant star with a pituitary problem. You eagerly move over to the main eyepiece and after you've focused out as far as your rack-and-pinion will stretch, find that you've locked onto a red aircraft warning light atop a TV antenna half a mile away.

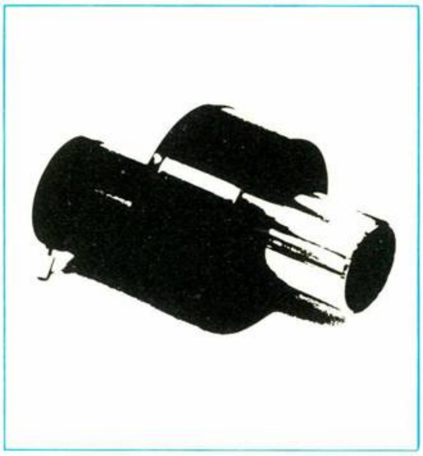
This isn't to say such finders have no merits — of course they do. They're fine additions, especially to short-focus reflectors and catadioptrics. But you must know how to use them and that takes some time. Get to know your finder first, okay? Then try bigger and better things if and when you need to, not before.



courtesy Celestron

3. "I'll Need a Pack of Eyepieces. Different Guns for Different Game, You Know!"

Take my advice, please. Do *not* sell your great-grandmother's priceless eagle-claw dining table (the one Ulysses S. Grant spilled turtle soup on) to finance the sixty-four eyepiece menagerie you've finally settled on. All you can do with 64 of the wretched things is wonder what to store them in, how to keep them in order, how to locate each one in the dark, and how to return home from observing with sixty-four instead of fifty-eight.



courtesy Optical Techniques

Face it, unless you're gonna use them for chess pieces, you don't need that many.

Granted, you will probably need a few more eyepieces eventually. When a dealer sells a telescope, he's careful to include in the base price those eyepieces that will give a modest and usable range of powers and keep the instrument's price well within the competitive range. This is fair and understandable business practice.

But until you've thoroughly used the eyepieces provided, you have no way of knowing what other ones you really *do* need. After fifteen or twenty careful observing sessions, you'll begin to see where your present eyepieces are good and where you could profit from another one or two. Then and only then should you consider adding to your collection.

When that time comes, think in terms of *quality*, not *quantity*. If you cannot afford state-of-the-art orthoscopics, purchase quality Kellners instead. In the case of long-focus refractors or reflectors, Kellners often perform as well as orthos and are considerably less expensive. In any case, make sure they are the right size

MA6mm
MA9mm
MA12mm
MA25mm
MA40mm
OR4mm
OR6mm
OR9mm
OR12.5mm
OR18mm
OR25mm
MULTI-COATED
Meade

courtesy Meade Instruments

to fit your focuser.

And take it from experience, you can wait quite a while for that high-powered 4 mm eyepiece. Rarely will our atmosphere permit you the pleasure of doing more than taking it out of its warm little nest and then putting it back (probably in the wrong slot). And anyway you'll soon grow out of thinking of your telescope as a high-magnification instrument only.

Along with the eyepieces, purchase the best Barlow (negative) lens you can find. These lenses amplify the power of the eyepiece they are used with. Before selecting such a lens, pay special attention to the clear aperture of the achromatic lens and its amplification. The larger the aperture, the better (as long as it will fit the drawtube of your focuser).

These lenses are readily available in amplification powers of 2x, 2.4x, and variable power 2x-3x. It is very important to select a Barlow lens that will not waste your eyepieces' time. For instance, if your eyepiece collection includes an 18 mm, a 12 mm, a 9 mm, and a 6 mm, all you'll get with a 2x Barlow is a seldom used 3 mm eyepiece out of that 6 mm. With the others, you're simply duplicating the powers you have already (albeit with some added eye relief). A 2.4x or a variable power Barlow lens would be the better choice in such a case.

A good selection of eyepieces for a 2x Barlow lens would include a 20 mm Erfle, an 18 mm, a 12 mm, and a 7 mm. The 2x lens then gives you the equivalent of a 10 mm, 9 mm, 6 mm, and 3.5 mm set. No duplications.

Horror stories sometimes go around about Barlow lenses. It seems that when combining negative lenses and eyepieces, the resulting marriages are not always made in heaven. When a lens of poor quality is coupled with a quality eyepiece or vice versa, only one thing can happen — incompatibility.

Even the best negative lens will make an eyepiece of poor quality seem twice as poor. And the night's rotten seeing will probably do the rest. Divorce will soon follow and chances are it'll be the Barlow lens, not the lousy eyepiece, that gets put out to pasture. What a waste!

Remember, in optics, quality should marry quality.

4. "I've Got to Have an Astrocamera. Next Month, I Want to See My Astrophotos All Over ASTRONOMY Magazine!"

You've already got a priceless camera in your head — your eyeballs. And what about that fantastic darkroom you couldn't live without — your brain? Have you given them a chance?

I have logged well over two hundred eyepiece hours observing the Dumbbell Nebula alone. Yet I will never photograph it. I know it too well. The photo would only be anticlimactic. It wouldn't do the nebula justice.

The picture in my mind is a 200+ hour exposure, unblemished by reciprocity failure or film grain. Of course, I can't show it to you, but you can have your own version, more or less like it, with only a bit of effort and dedication. Just get outside with your telescope and start the exposure. Observe and study.

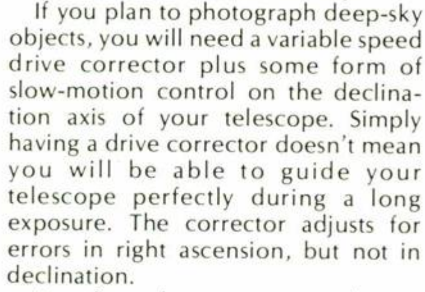
There is plenty of time to buy a camera and begin the trials, pitfalls, and tribulations of astrophotography later. Why aggravate yourself with underexposures, overexposures, drive errors, and the like so soon? Try observing — seeing — the heavens' wonders before you even consider photographing them. And by observe, I mean OBSERVE. Quick thirty second glances don't count. Only hours at the eyepiece can train your eye to see.

When you know beyond a doubt that you are ready for an astrocamera, realize first that they are not inexpensive, and that you will have to purchase certain extras if your camera is to pay off with beautiful astrophotos.

Unless you are content with short, unguided exposures of star trails and the Moon, you will need a quality equatorial mounting and motor drive. You will need to know how to align your telescope accurately on the pole, balance it properly, correct inherent drive errors, and most important, how to find pleasure in such activity.

If you plan to photograph deep-sky objects, you will need a variable speed drive corrector plus some form of slow-motion control on the declination axis of your telescope. Simply having a drive corrector doesn't mean you will be able to guide your telescope perfectly during a long exposure. The corrector adjusts for errors in right ascension, but not in declination.

Your first telescope may not have a declination control that is slow enough or smooth enough for long-exposure astrophotography. If it doesn't, you will have to obtain one. Some commercial telescopes come equipped with an electric declination slow-motion designed primarily to slew the telescope and/or help center an object in the field for visual observation. Some have a definite lag in their control response. Such controls are fine for cruising the stars, but are of little help in astrophotography when you need to nudge that teensy guide star just a tad to bring it back under the crosshairs of your illuminated reticle guiding eyepiece.



courtesy Celestron

Take into consideration also that when and if you decide to really get into astrophotography, you'll be committed not only to fabricating or buying an astrocamera, camera

adapters, guiding eyepieces, guide telescopes, and extra counterweights, but also to working with special films, learning special developing procedures, and mastering special photographic enlargement and printing techniques. Thus, a well-equipped darkroom begins to loom large in your plans.

This, of course, takes time and money. Very soon (in fact, appallingly soon) you can have more money sunk into photo-accessories than in your telescope. That once-modest, basic instrument abruptly represents a sizable sum. What's more, you've been so busy creating the perfect setup that you've had no time to observe. You've missed the fun, the glory of it all.

Suddenly, you find a great responsibility resting upon your shoulders. And it weighs heavily. If you are to make that investment pay, you've got to come up with some stunning astrophotographs. And that, you'll quickly learn, ain't so easy.

Be advised: Those beautiful photos that so often adorn these pages did not come easy. Beneath all of that infinite beauty and grandeur lies hidden a good deal of the photographer's "blood, sweat, and tears." For this reason alone, you should not merely glance at the photos. Appreciate them. Take the time to read the photo credit. Each of those photos is the work of some devoted, caring astronomy enthusiast who's paid his dues — and put time, effort, and money into perfecting his work.

Everyone must pay their dues, even you. But luckily you don't have to pay them all in one lump sum. Before you spend more on a complete astrophotography setup, be very sure you have taken full advantage of your present outfit. Astrophotography and its accessories are an exciting and integral part of the enjoyment of astronomy, but they are definitely not for the novice.

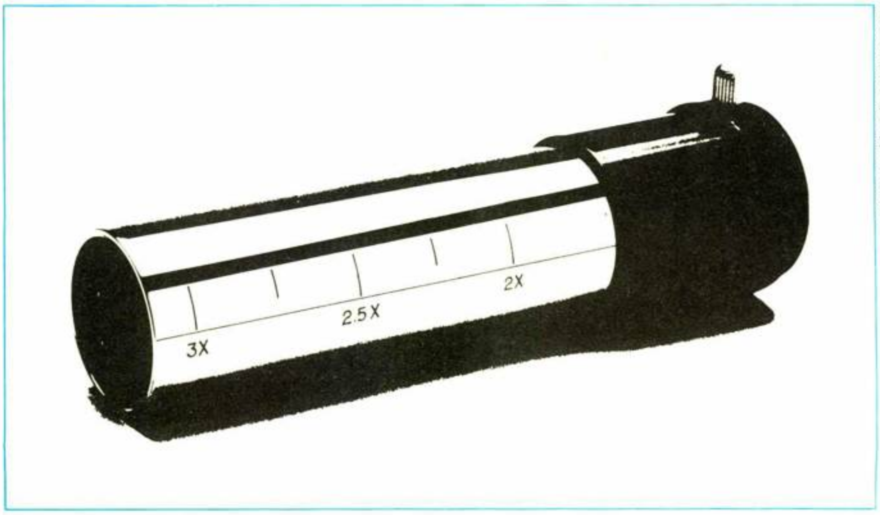
Be sure you are ready, then go ahead. But tread softly.

5. "I Can't Help It. I Want Everything. Everything!"

And, as you've no doubt already noticed, everything costs money. But when the Fever hits you, monetary objections melt away. "Money is no object. I need it," you think. You haven't even got an A.A. (Accessories Anonymous) to get you through those long, dark, lonely, equipment-starved nights.

If you don't keep control of yourself, you'll order away like a lunatic. In one fell swoop, you will deluge the mails with orders for safe sun screens (and you're not even interested in the Sun), nebular filters, Moon filters, accessory cases and trays, telextenders, telecompressors, electronic timing devices, every book in the book, rechargable energy packs, power inverters, dewcaps, personalized astronomical flashlights, automatic trackers, hydrogen-alpha filters (the Sun again!), richest field conversion units, and even digital right ascension and declination readout consoles.

Why, you can even purchase a complete television rig that will allow you to observe in the comfort of your own den, proud as a peacock, in living color. Every month, new, exciting, and innovative items come on the market. Does this mean astronomy has sunk to the level of a "status sport" for the affluent? Luxury observing has arrived — where will it all end?



courtesy Meade Instruments

I can already see the next step: Rent-an-Observer, Inc. This company will, for a nominal fee of about $129.95 a night (half-price if it's cloudy), rent you a fully-equipped human being who will take your telescope out to your favorite observing site, observe and photograph the four (4) deep-sky objects of your choice, and return your telescope to your storage area at sunrise.

courtesy Meade Instruments

Just think: You won't have to fight the cold, dew, bugs, the misalignment problem, or your runny nose. You can even go out to the movies! Won't that be great?

Let's hope that never happens.

Let's never lose touch with the real pleasure of amateur astronomy — the observing, the appreciation of our limitless universe and its unbelievable beauty. That's what's really important; all the gadgets and paraphernalia should only be a means to this end.

Most telescope accessories are truly useful items and have their place in astronomy. But never let carelessly bought accessories turn a practical telescope into an overgadgeted, overweight monster.

If you take care, use your good sense, be patient, and just let things happen gradually, you won't create that monster. You will not become an astronomical Dr. Frankenstein.

Take it slow and easy.

Be gentle with your new telescope.

Be gentle with your funds.

Be gentle with yourself.

And observe, fellow astronomer, observe and enjoy!

Ken Fulton is a dedicated amateur astronomer and writer who often comes up with articles like this one. If you want sound advice on buying a telescope "painlessly," go check out his "Read 'Um and Don't Weep" which appeared in the July 1979 issue.

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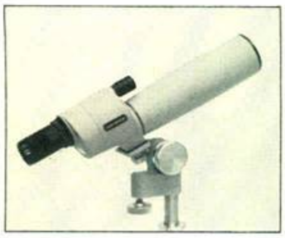

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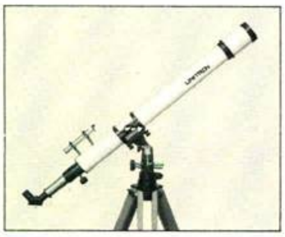
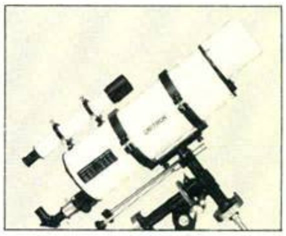


4″ Compact Refractor



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ASTRONOMY IN FOCUS

Primeval Black Holes

Sir / I thoroughly enjoyed reading your article "The Quasar Connection" in the December 1979 issue. However there is one aspect of the theory that puzzled me. The theory hypothesizes that quasars could be an early stage in the evolution of galaxies — the energy source of the quasar being the accretion disk surrounding the centralized black hole. You further theorize that the distant quasars are perhaps remnants of the initial Big Bang. Now assuming the definition of a black hole as being the final stage of a collapsed star, how could collapsed stars have existed so early in the time scale following the Big Bang (assuming normal time scales for star evolution from formation through main sequence)?

Kenneth Messer
New Hyde Park, NY

Mr. Messer / Let me begin by making a slight correction in your observations. While it is true that a black hole is believed to be the final product of gravitational collapse for stars above approximately 3 solar masses, this does not provide us with an adequate definition of the term "black hole." Rather, a black hole is "defined" as any region of space in which the gravitational field is so strong as to prevent light from escaping.

Black holes may have been formed in great numbers in the period immediately following the Big Bang, and not as a result of stellar collapse. Any region of that early cosmos in which there existed a local dominance of gravity over all opposing forces (radiation pressure, degenerate particle pressure, and so on) would have been a prime candidate for black hole formation. Stephen Hawking's "mini-black holes" may have evolved at this time.

Even though a variety of black hole formation mechanisms present themselves, we shouldn't be too hasty to discard the more obvious process of stellar collapse. The more massive a star is, and they exist with up to 60 times the Sun's mass, the shorter its lifespan. The heaviest stars of all can barely survive for 100,000 years before terminal gravitational collapse sets in and they are squeezed down the throat of a self-made black hole.

Compare the figure of 100,000 years with the age of the most distant quasars. Even the highest red-shifted, most remote of these peculiar objects are still being seen as they were over 1 billion years after the Big Bang! In principle, then, many hundreds of generations of black-hole-doomed stars could have been contributing to a central super-massive collapsed object within the quasar. As the nuclear black hole grew, so would the extent of its accretion disk and, in turn, the power of its energy-generating mechanism.

David Darling

Astounding Proposals

Sir / In the Forum section of the January 1980 issue, Thomas Morgan had a brief article on "Solar Sailing." Although I found his article generally informative and interesting, I was puzzled by his slighting reference to the magazine *Astounding Science Fiction* (page 25).

Amongst other phrases, Mr. Morgan referred to *Astounding* as "one of the sensationalistic pseudoscientific periodicals of those days..." This seems to judge a science fiction magazine as a technical journal; should we call any fiction "pseudolife"?

Actually, *Astounding* was undoubtedly the most respected science fiction magazine of its time, and, when the article in question appeared (May 1951), had been continuously published for 21 years. (It continues to be published, although its name was changed to *Analog* in 1960.)

Each issue characteristically had one (sometimes two) article on scientific topics, sometimes speculative in nature, but to judge this respected fiction magazine as a "pseudoscientific periodical" seems a most unbalanced judgement.

By the way, *Astounding* wasn't a "dime magazine"; the May 1951 issue cost me 25 cents. Actually, I don't think there were any "dime magazines" in the 1950s, except perhaps comic books with which Mr. Morgan may be familiar.

John E. Westfall
San Francisco, CA

Fine Winter Sights

Sir / I am fifteen years old, and I've enjoyed astronomy as a hobby for the past three years. I believe that the upcoming winter months are going to be a definite bonus to any astronomy lover. First of all, there are up to fourteen hours of darkness, plenty of time for any observer. Also, there are no mosquitos or other pests, and atmospheric haze is at a minimum.

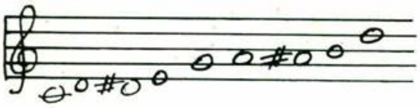
As another added attraction, we have two major meteor showers within three weeks of each other. They, of course, are the Geminids and Quadrantids. Each is supposed to produce up to fifty "shooting stars" per hour, although most of the Quadrantids will be smothered by moonlight. I may seem foolish to sit in the cold, but when one of those extra-bright meteors cuts through the heavens, you may suddenly feel a surge of warmth.

Last, but definitely not least, the winter constellations are unveiled one more time. The majestic Dog Star, Sirius, is simply dazzling, even more so through a good-size telescope. The Beehive in Cancer and the famous Pleiades, two of my favorites, are magnificent through binoculars. Constellations like Orion, Taurus, and Gemini speak for themselves. Nothing in nature beats the winter skies — the ultimate in astronomy.

Steve LaFlamme
Raynham, MA

Music of the Spheres

Sir / Re: "Listen to the Wandering Stars" in the January 1980 Forum, an ascending musical scale uses sharps instead of flats, which are reserved for descending scales. What we should hear is the same as printed, but noted:



These notes should be sounding more or less simultaneously — the dissonance being very beautiful when heard many octaves higher than the notation.

Bruce A. Montella
Unionville, CT

Naked-Eye Satellites

Sir / In regard to the Gazer's Gazette ("Jupiter's Miniature Solar System") in the February 1980 issue, I have tried observing Jupiter's moons without optical aid many times, but have failed to see them. After reading the article I was inspired to try again.

On the morning of January 19, when Jupiter was in the western sky, I tried to spot the moons by partially blocking out the glare of the planet. Not noticing any moons, I used a pair of binoculars to spot them and found Ganymede was on the west edge of the planet. Knowing where the moon was I was amazed at how easy it was to see with the unaided eye (well, not *that* easy). Then on the night of January 23, Jupiter was shining through an exceptionally clear atmosphere and was near the zenith. For the first time, I spotted the tiny moon on the west limb without the use of binoculars. I confirmed my result by using the binoculars later to find Ganymede elongated far on the west side of the planet.

Frank Plennert
Niagara Falls, NY

Ooops!

Our thanks to Marvin Mayo for pointing out that the photo of comet West which appeared on page 23 of the August 1979 issue should have been credited to George Carlisle and Marvin Mayo.

The photograph of the RY Leonis region in the Finder Chart on page 55 of the March 1980 issue is from the *Lick Observatory Sky Atlas*, courtesy of Lick Observatory.

behind the scenes | of telescopes...

Two more ASTRONOMY readers have become winners in our monthly early renewal drawing — and received their portable Astroscan telescopes as prizes. They are Raymond Loomis of Tiverton, Rhode Island, and David Smith of Port Orange, Florida.

Mr. Loomis had given ASTRONOMY as a gift to a friend, so when he won, he wasn't sure whether to keep the telescope or give it to his friend. They conferred, and he kept the telescope. "Although I have a minimum interest in astronomy, my two sons, aged 10 and 12, are studying astronomy in science and love the Astroscan. You can imagine how that added to the dilemma! Now I am sure the warmer months will find the three of us out there under the stars. Anything that sparks learning is a boon as far as I am concerned — it is a beautiful instrument and was well chosen as a prize to be given." Mr. Loomis teaches industrial arts.

Our other winner, David Smith, is a barber. He says of himself: "I've always had an interest in astronomy. I've got all the latest literature including ASTRONOMY magazine, and my library is full of astronomy books. As a kid in elementary school, I was always reading all the astronomy books and magazines I could. Then I'd go outside and lay down and look at the stars. I've used the Astroscan quite a bit since I got it and I really enjoy it."

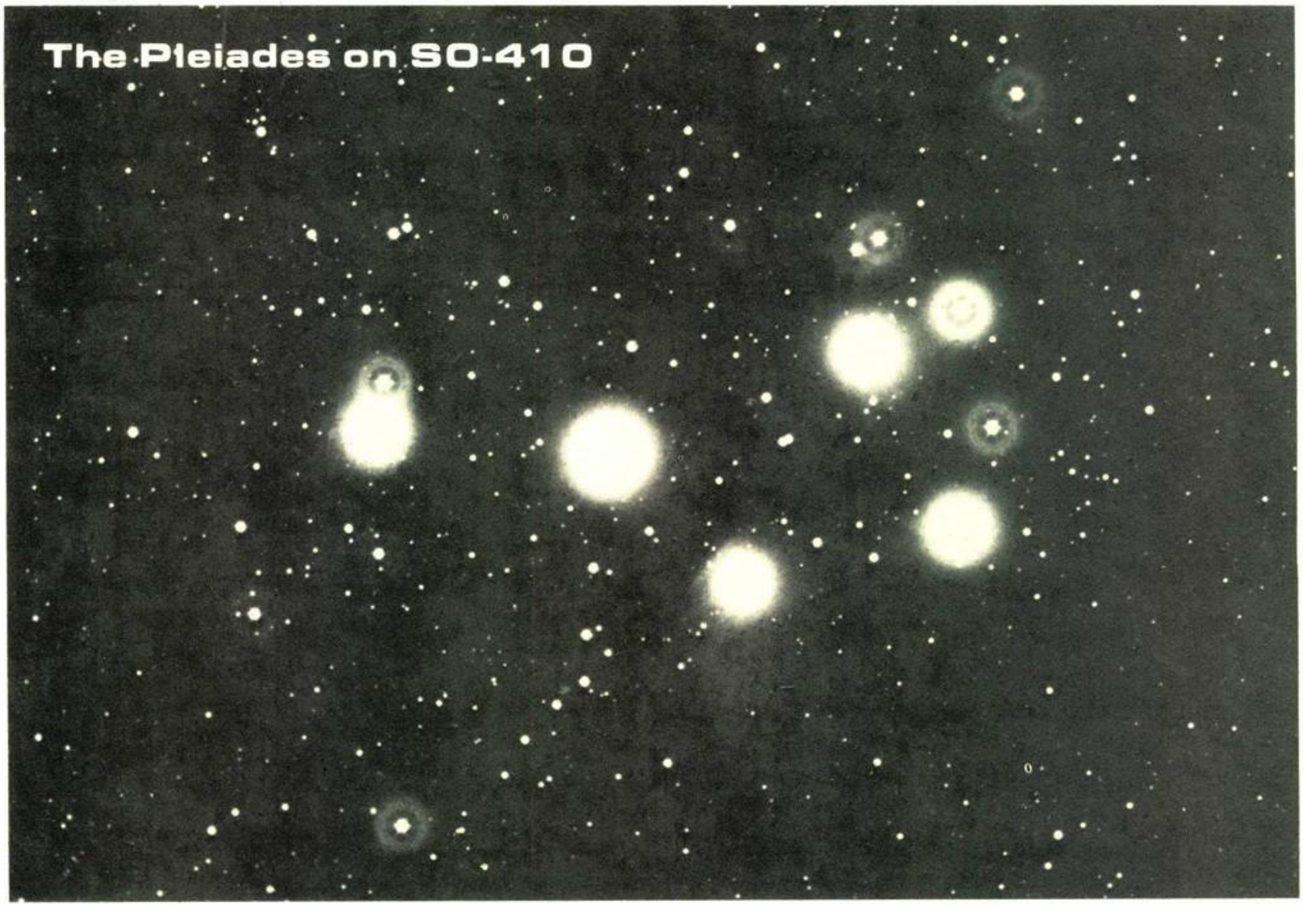
This month, Forum carries an interview with another man who has spent a lot of time looking at the stars. He has also made an important contribution to the hobby of astronomy by helping tens of thousands of people to see the Moon, the planets, and the stars through the telescopes of the San Francisco Sidewalk Astronomers. It's certain that many of those people had their lives enriched by that short stint at the eyepiece. One nice thing: If you like the Sidewalk Astronomers and want to help their work, you don't have to live in San Francisco. Their members come from all over the world.

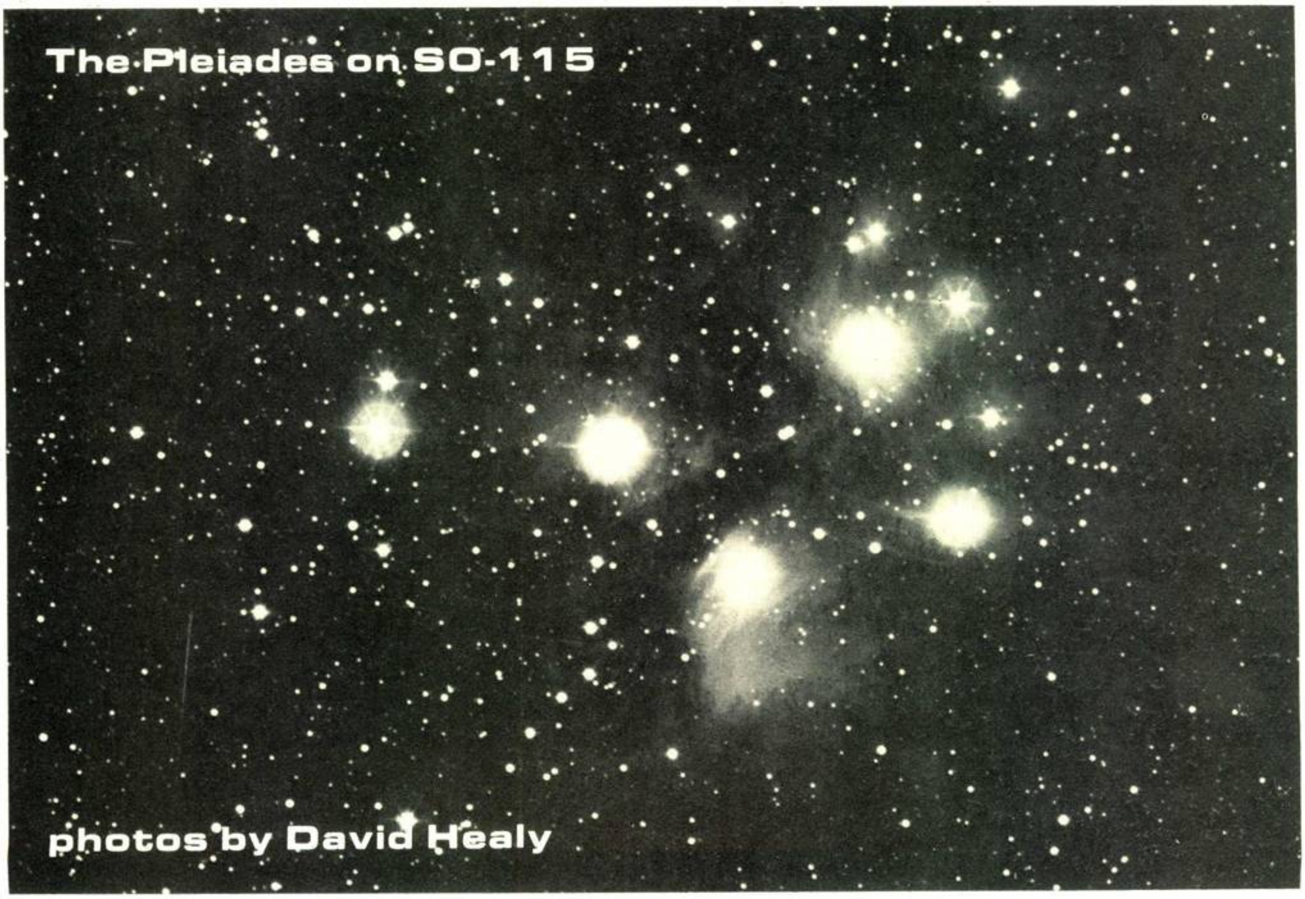
By the way, if you're curious about Dobsonian telescopes, or want to build one yourself, two issues of *Telescope Making*, #4 and #5, carried articles on them. (You can order these back issues at $2 each.) Your Editor, who also just happens to be the Editor of *Telescope Making*, is something of a convert to this type of telescope, and early this year put his own 20-inch Dobsonian into operation.

Sincerely,

Richard Berry

Richard Berry


The Pleiades on SO-410


The Pleiades on SO-115
photos by David Healy

using SO-115 film

photography
in
astronomy

by
David Healy

If you've tried your hand at astrophotography, you've probably run head-on into one of the limitations of photography: film grain. Your negatives, which looked so great before you enlarged them, suddenly revealed a salt and pepper pattern that broke up fine detail in lunar shots, swallowed dim stars, and relegated faint nebulae to misty obscurity. Bigger and bigger telescopes, with correspondingly bigger image scales, are one way (an expensive way) to beat the grain problem. The other way is via better films.

Now Kodak has added a powerful new tool to the astrophotographer's kit: Technical Pan Film SO-115. If used properly, it can, because of its extremely high resolution and enlargeability, overcome the limits imposed by the tiny 35 mm film format.

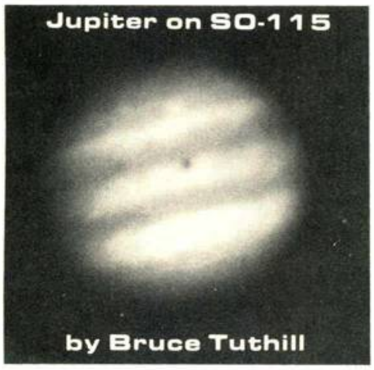
Why is SO-115 Better?

Why a new fine-grain black and white film should be of particular interest to astrophotographers requires a bit of background. Specialized, high-resolution negative films have been available in 35 mm for some time: High Contrast Copy, H&W Control, SO-392, and SO-410, to name a few. All of these, however, had important drawbacks, especially for deep-sky photography. They have slow speed, limited spectral response (especially to red light), narrow latitude, and halation.

The old SO-410 film was pretty good stuff. No film grain was apparent even under magnification, most star images were extremely tiny, and the film recorded stars down to the 16th magnitude, some 10,000 times fainter than the dimmest visible to the naked eye.

Despite all these virtues, however, a negative I took of the Pleiades taken with an 8" Schmidt camera was scarcely worth printing. For one thing, practically none of the Pleiades' nebulosity showed up in the photograph, but more important, the images of the brighter stars in the cluster (which are about third magnitude) recorded as enormous blobs — more like photon torpedoes than stars.

SO-410 film, however, has been replaced by SO-115. Halation, and with it the giant blobs, is under control. What happened? In the old SO-410 film, light from the brighter cluster stars reflected off the surface of the film's base and scattered through the emulsion, causing the oversized star images — an effect known as *halation*. In SO-115, there is a dark "anti-halation" chemical layer beneath the emulsion.


Jupiter on SO-115

by Bruce Tuthill

Unlike the 103a series spectroscopic films whose rem-jet anti-halation backing must usually be wiped off by hand, SO-115's anti-halation layer disappears, due to chemical reactions, during normal film processing.

Furthermore, the new film's spectral response (i.e., its sensitivity to light of various colors) is still greatest in the red, but the response in the blue-green region of the spectrum has been boosted sharply. Blue reflection nebulosity, such as that enveloping the Pleiades, shows up well with SO-115 doing the recording.

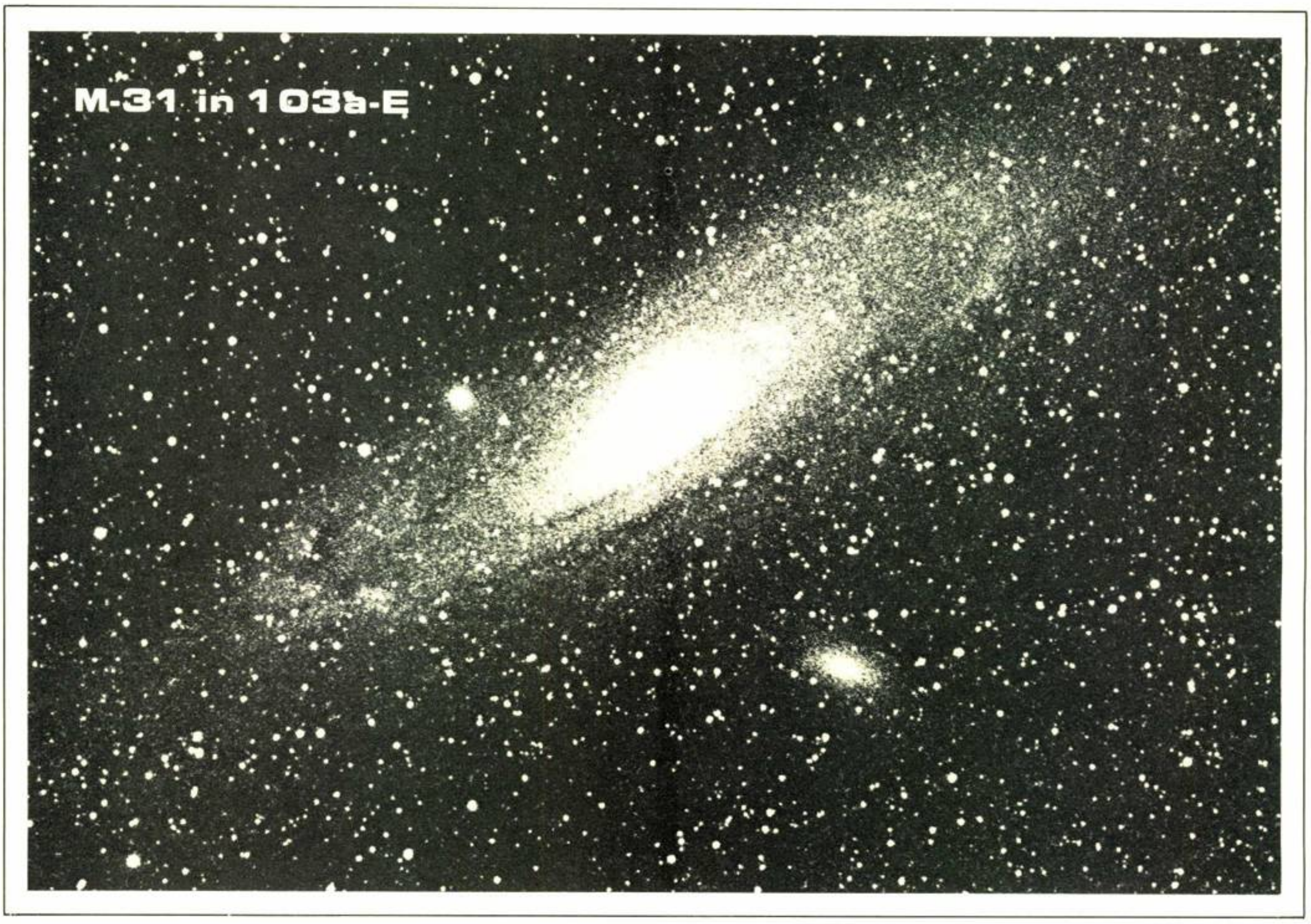
SO-115 vs. the Spectroscopics

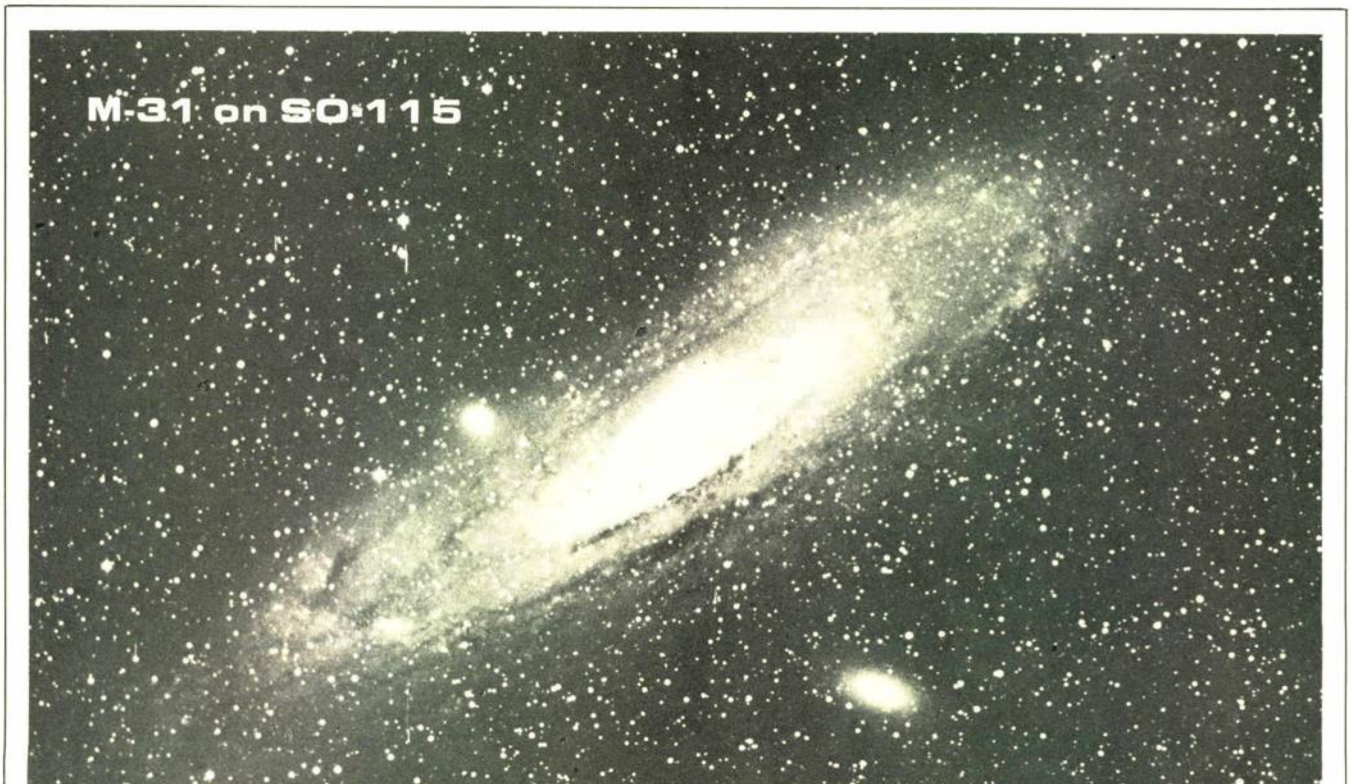
It is in comparison with the fast but grainy 103a series spectroscopic films that SO-115 really stands out as a deep-sky film. Comparison photographs taken of the same object with the same 8" Schmidt camera show pinpoint star images and vastly superior detail using SO-115. In fact, the fine grain of SO-115 enables the astrophotographer, if the optics of his instrument permit, to transcend the usual limitation imposed by the 35 mm film size.

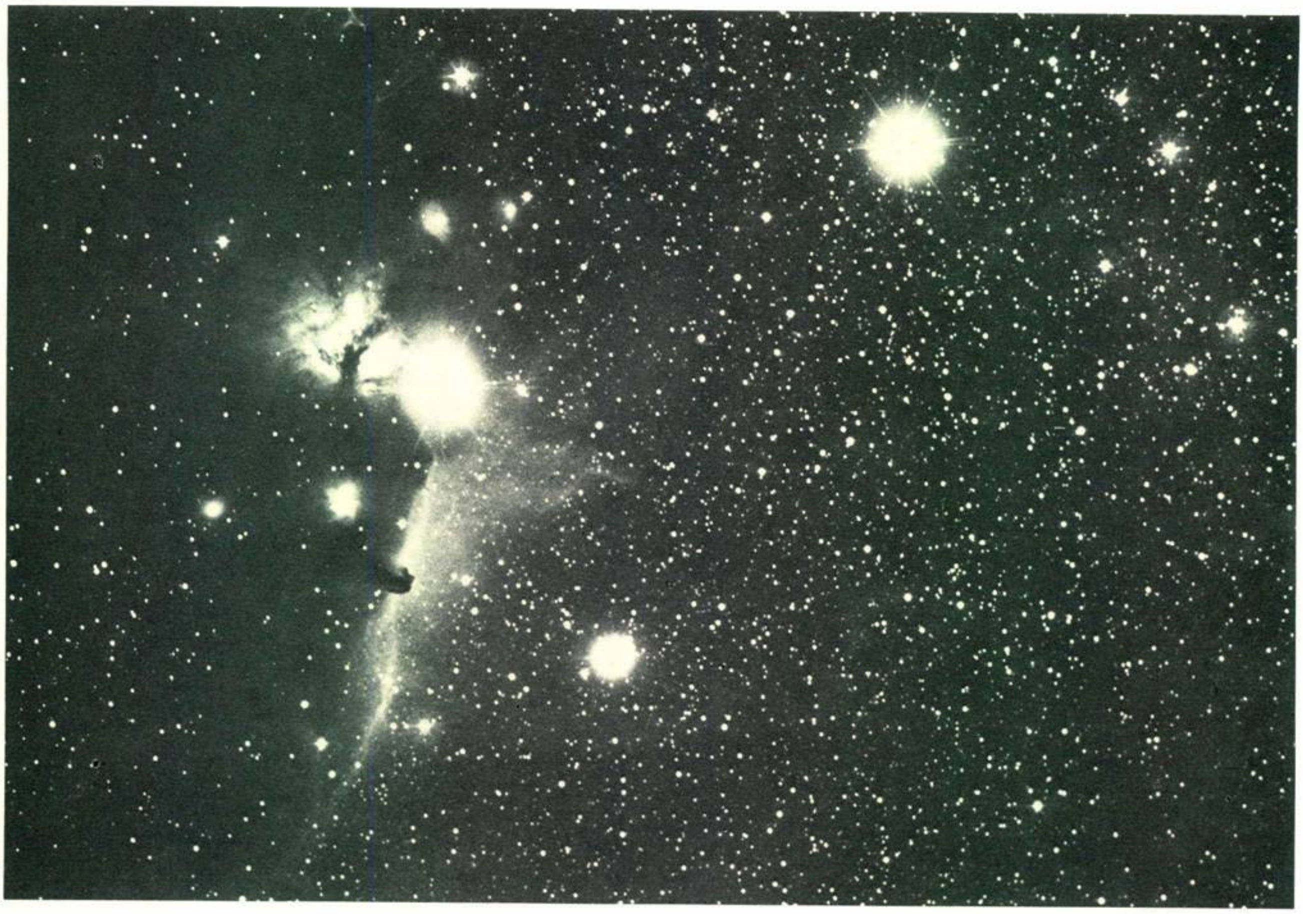
SO-115 negatives can have enough resolution that great enlargements don't spoil the "professional look" usually achieved only with larger-size film formats. And unlike the 103a series spectroscopic films which require freezer storage, SO-115 is not unusually perishable and can be handled like any ordinary film.

The drawback of SO-115 as a deep-sky film, however, is its relatively slow speed. Developed for maximum contrast in D-19 developer, SO-115 has a theoretical ASA rating of 160, but in practice, using an f/1.5 Schmidt camera, it requires at least ten times the exposure that 103a-E film does to reach a comparable density. With the Schmidt, this results in a tolerable exposure time. SO-115 requires a 30-minute exposure versus about three minutes for 103a-E to reach the sky fog limit dead overhead in a dark sky. This suggests that after the effects of reciprocity failure are taken into account, the real speed of SO-115 at f/1.5 and at deep-sky light levels is about 60 ASA.

For deep-sky photography, then, SO-115 is useful only with very fast optical systems. Schmidt cameras, of course, are one such system, but don't forget the ubiquitous 35 mm camera lens. If you own a 35 mm single lens reflex (SLR) camera, chances are the lens is faster than f/2 — adequate for making stunning pictures of the Milky Way (see "Piggybacking — Without a


M-31 in 103a-E


M-31 on SO-115
photos by David Healy



The Horsehead Nebula was taken on SO-115 with an 8″ f/1.5 Celestron Schmidt camera. The exposure was 25 minutes from the clear skies of Naco, Arizona. Photograph by David Healy.

Drive," ASTRONOMY, April 1979).

Unfortunately, SO-115's slow effective speed means that exposure times with telescopes (most of which have focal ratios in the f/5 to f/12 range) will be impractically long, except for the brighter deep-sky objects. There may be ways to speed up SO-115, as is done with some other films, so it would be admirably suited for experiments with cold cameras or hypersensitization.

Solar, Lunar, and Planetary

SO-115 is an excellent film for solar, lunar, and planetary photography. Kodak thinks so too: SO-115 replaces SO-410 ("Photomicrography Monochrome Film") and SO-392 ("Solar Flare Patrol Film"). SO-115 has considerably more exposure latitude than High Contrast Copy film which, annoyingly enough, can be overexposed at 1/30 second exposure and underexposed at 1/60. It also has considerably more speed than High Contrast Copy, especially desirable in photographing Saturn.

Since SO-115's grain is almost negligible, it permits high enlargements from tiny planetary images. Whereas Tri-X looks too grainy at more than 10x enlargement, you can push SO-115 to twice or three times that. Also helpful in photographing planets, its contrast can be varied by using different developers or dilutions.

Developing SO-115

Kodak recommends D-19 developer (4½ minutes @ 68° F) for "maximum" contrast. This would be desirable for most deep-sky use and for some solar system photography.

"High" contrast is achieved by using HC-110 developer at its dilution D (8 minutes @ 68° F), and "moderate" contrast with HC-110 at its dilution F (also 8 minutes at 68° F). There's a penalty for moderate contrast though: the exposure index drops to 80 ASA from the usual 160 ASA.

Astrophotographers have experimented with lots of other developers, too. It's fun to do such experiments, and you may get good results with SO-115 developed in such soups as Microphen, Diafine, and Rodinal.

Availability

The "SO" in the SO-115's designation once meant "Special Order." SO-115 now goes under the moniker "Kodak Technical Pan Film," and some photo dealers will order it for you. Its catalog number in 135-36 loads is 129-7563, or you can order it by the 35 mm by 150-foot spool, SP 651, as stock number 129-9916. Prices have recently gone up, as they have for all films, because of the increasing price of silver.

One convenient mail-order source for the film is Astro Cards, P.O. Box 35, Natrona Heights, PA 15065, which offers both the 36-exposure cassettes and the 150 ft. rolls. Another source is the *Astrograph* magazine, Box 2283, Arlington, VA 22202.

Your local photo dealer should be able to get D-19, HC-110, and other developers if they don't have them in stock. If they say they can't, try contacting Eastman Kodak Company, Amateur Photo Information Service, 1133 Avenue of the Americas, New York, NY, phone (212) 930-7656.

If your corner drugstore won't process SO-115, try a custom lab, or better yet, develop it yourself! Processing black and white film at home is relatively simple and requires a minimum investment in equipment.

When David Healy isn't taking pictures of the sky with his Schmidt camera, he's a chartered financial analyst — you'll even find him quoted in the Wall Street Journal*!*

AstroNews

1981 NASA Budget Submitted to Congress

The proposed fiscal 1981 budget for NASA as submitted by the Administration to Congress denies new-start funding for an ion-drive stage, virtually killing scientists' hopes of flying a single spacecraft past Halley's Comet and comet Tempel 2 later this decade. But it does include money to start two major astrophysics observatories — the Gamma Ray Observatory and the Cosmic Background Explorer — and a twin space physics explorer.

Announced January 28 in Washington, the budget plan requests $5.7 billion for NASA, a 15% increase over what was requested for the current budget. However, there is also a request for $300 million to be added to the current budget to bail out the financially and technically troubled Space Shuttle.

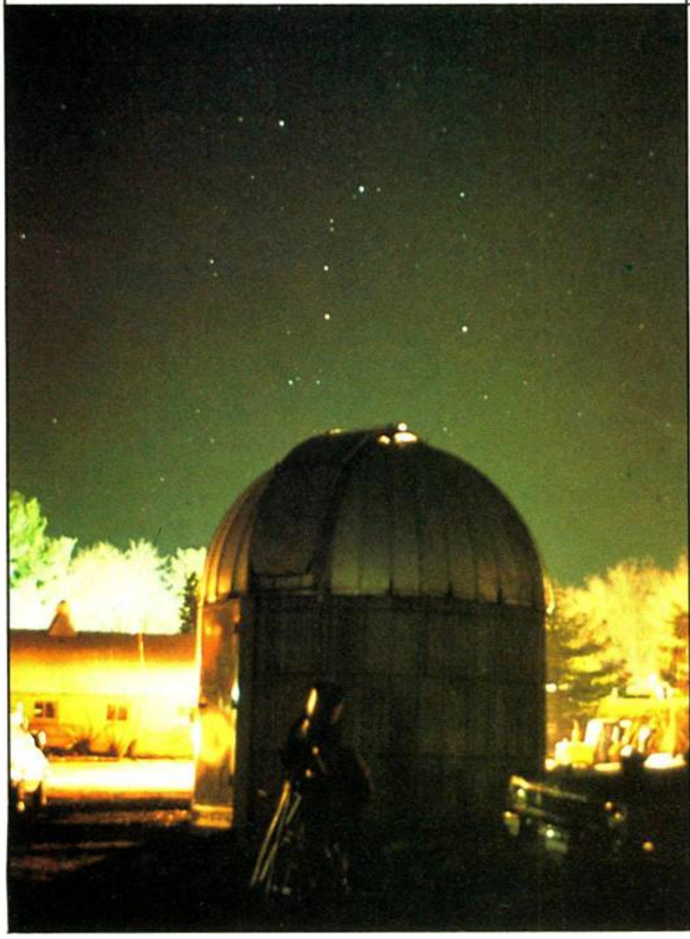
Needed to launch the comet mission is the solar electric propulsion stage (SEPS), an advanced ion-drive rocket that can operate only in the vacuum of space and cannot even lift its own weight off Earth's surface. But the efficiency of its power per pound of fuel — which is ionized and electrically propelled — is several times greater than that achieved by chemical rockets, and the drive would be capable of operating continuously for many months or even years. SEPS is the only way that a spacecraft could be propelled on the high-energy trajectories needed to reach Halley's Comet, then fly on to comet Tempel 2. The mission is unique, and Halley's will not return for another 76 years.

NASA wanted $20 million to start advanced development work on SEPS so it would be ready for launch in 1984. But when the final numbers were to be added up, and NASA Administrator Dr. Robert Frosch was told to make a choice, the Gamma Ray Observatory was accepted, not SEPS.

The Gamma Ray Observatory (GRO) is "in much better definition," Frosch told a news conference, and added that he felt that was also the consensus of the science community. The comet mission is not as fundamental to cosmic physics as GRO is, he said, and the latter is "more likely" to have a Nobel prize result from its work, an allusion to potential discoveries from the Gamma Ray Observatory.

Also missing from tne budget proposal was the Venus Orbiting Imaging Radar (VOIR), which would map the surface of Venus by using synthetic aperture radar (see "Alien Eyes" in ASTRONOMY, January 1980). Its loss is considered to be less critical as Venus opportunities recur more often — every few years — than those for Halley's Comet.

A total of $439 million is to be allocated for physics and astronomy missions (see table). In planetary exploration, the total is $180 million, including funds for Galileo, the orbiter and probe missions to Jupiter. Another $20 million was requested for SEPS, and $30 million for VOIR, but it was refused.



Light Pollution Photo Contest

Winners of the Light Pollution Photography Contest sponsored by the Astronomical League, the national federation of astronomical societies and individuals, have been announced.

The competition sought photographs illustrating the problem of light waste and its effects on astronomy as well as examples of solutions to the problem. Entries were received from as far away as Italy, demonstrating that "Light waste is an international problem facing the scientific community," according to Robert R. Young, League president.

First place winner was Rick Armstrong of Satellite Beach, Florida. His black and white photograph shows a spotlight-lit school tennis court installed next to Satellite High School's observatory housing a 16-inch telescope. Installation of the courts and night lights next to the existing observatory has provided the school's astronomy students with "probably the most secure, brightly lit observing site in the state of Florida," according to Armstrong, thereby destroying its usefulness for astronomy.

Armstrong won as first prize a Quantum 4 telescope donated by Optical Techniques, Inc., of Newtown, Pennsylvania. Valued at $1000, the instrument is the first of an annual series of the firm's telescopes to be presented by the League to a deserving amateur astronomer who has made a notable contribution to the science.

Dennis A. Leatart of Oxnard, California, placed second with his color photograph, "By the Light of the Silvery Moons..," showing bright mercury vapor lights and the full moon at Oxnard, California. Third place was secured by Ed Kaczanowicz of Philadelphia, Pennsylvania with a color photograph (left) of light waste at the Kepler Observatory on Temple University's Ambler, Pennsylvania campus. The constellation Cassiopeia is seen over the 11-foot dome and contrasts sharply with colors of light fixtures near the observatory.

NASA Budget

SPACE SCIENCE	FY1980	FY1981
Physics and Astronomy		
HEAO development	2.1	--
Solar Maximum Mission development	3.1	--
Space Telescope development	112.7	119.3
Solar Polar Mission development	47.9	82.6
Gamma Ray Observatory development	--	19.1
Spacelab development	40.9	72.1
Explorer development	32.3	33.0
Mission operations, data analysis	37.1	38.9
Research and Analysis	34.1	42.8
Suborbital Programs	26.9	30.9
TOTAL	337.1	438.7
Planetary Exploration		
Galileo development	116.1	63.1
Mission operations, data analysis	58.8	64.8
Research and analysis	45.0	51.7
TOTAL	219.9	179.6
Life Sciences		
Flight Experiments	16.6	19.2
Research and analysis	27.2	30.5
TOTAL	43.8	49.7
TOTAL SPACE SCIENCE	600.8	668.0
SPACE TRANSPORTATION SYSTEM (Incl. Shuttle)	2403.3	2738.2
SPACE AND TERRESTRIAL APPLICATIONS	343.9	394.8
AERONAUTICS AND SPACE TECHNOLOGY	427.1	409.5
SPACE TRACKING AND DATA SYSTEMS	332.4	359.0
TOTAL RESEARCH AND DEVELOPMENT	4107.5	4569.5
Construction of Facilities	156.1	120.0
Research and Program Management	1006.2	1047.2
TOTAL NASA BUDGET	5269.8	5736.7

(Figures in millions of dollars)

Despite the loss, there is still hope for the two-comet mission. Support is taking shape in Congress to have the funding restored, although it must pass four committees plus both houses and then be signed by the President. Scientists and industry are also preparing to lobby for SEPS.

In addition, definition studies for SEPS are continuing and probably will be continued through fiscal year 1981 even if SEPS does not become a new start. Boeing Aerospace and Lockheed Missiles & Space Co. were awarded identical $1.15 million contracts last fall for these studies. And selection of experiments will continue under the comet mission announcement of opportunity issued last fall.

Frosch told the press conference that NASA plans to seek new start money once again for SEPS in the fiscal year 1982 budget to be proposed next January. While that will not restore the full two-comet mission, it will make possible a ballistic flyby of Halley's and, on a separate mission, a rendezvous with Tempel 2. But NASA would have lost the 2-for-1 price advantage. And, scientists are worried — legitimately — that the accountants in the Office of Management and Budget, where final budgetary policy decisions are made, will decide that only one comet mission is enough.

The Gamma Ray Observatory will expand upon the work developed by the three HEAOs. Gamma ray astronomy is considered to be in its infancy, just as X-ray astronomy was in the 1970s. Several satellites have been flown with gamma ray instruments, but these have been very rudimentary. The Gamma Ray Observatory is expected to offer at least an order of magnitude better spatial, temporal, and spectral resolution than previous spacecraft.

The Cosmic Background Explorer will also look at a basic process, this time creation (see "The Cooling Fire of Creation," ASTRONOMY, March 1980). The 3,000-pound spacecraft will carry a set of four microwave radiometers and two super-cooled infrared monitors. The microwave radiometers will measure the 2.7° K cosmic background radiation with greater precision than ever before. They will be similar to the microwave instruments carried aboard a U-2 spyplane to discover the anisotropic nature of the background two years ago. The infrared instruments will measure radiation from dust and weak sources that overlap the 3° K blackbody curve so they can be removed from final data.

A pair of Explorer spacecraft will be launched within two years to help determine how particles cross the magnetospheric boundary from interplanetary space to near-earth space, and to determine whether they are also injected by the magnetotail. The project is known as the Active Magnetospheric Particle Tracer Experiment, or AMPTE.

The first of the two craft is a Charge Composition Explorer that will be placed in an orbit ranging up to 8 earth radii high, thus remaining within the magnetosphere of the Earth. It will conduct baseline measurements of ions and magnetic fields around the Earth. Later, the ion release module will be placed in an orbit ranging out to 20 earth radii, well into interplanetary space outside Earth's magnetosphere. It will inject lithium into the solar wind at a point between Earth and the Sun. Measurements by the charge composition explorer will indicate how much of the solar wind leaks across the bow shock. Seven months later, when the ion release module's orbit has precessed 180° and it is behind the Earth as seen from the Sun, it will inject lithium and, later, europium into the magnetotail extending from the Earth away from the Sun.

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AstroNews

Again, the charge composition explorer will look for ions arriving in the low earth orbit neighborhood.

Other new starts in the budget are the National Oceanic Satellite System, an advanced communications satellite technology program, and a new remote sensing effort.

The Space Telescope, which was nearly dropped from the NASA budget several years ago, continues under development, although its initial launch may be delayed because of the problems afflicting the Space Shuttle. Dr. F.A. Speer, who has been the manager of the immensely successful HEAO program, has been selected to become the manager of the Space Telescope project. The Space Telescope will enable astronomers to see seven times deeper into space than is now possible with ground-based instruments. It will expand the volume of space open to observation by 350 times, revolutionizing astronomy.

Stellar Mixmaster

Observations made by scientists of the Naval Research Laboratory with the NASA HEAO-1 (High Energy Astronomy Observatory) have detected surprisingly intense X-ray emission from a pair of common variety stars much like the Sun in the constellation Cepheus.

The two components of the double star VW Cephei are gravitationally locked in a very tight embrace, forming what is called a contact binary. So small is the separation that they share a common corona and whip around each other with a period of only six hours. One star is 10% more massive than the Sun, while the other is about half the mass of the Sun.

The stars nest inside their shared outer atmosphere like two egg yolks in the envelope of a single shell. The stars may partake of a rotary motion, resembling the counterrotation of the twin blades of an egg beater. In the space between the stars, as in the egg beater, the intervening gas may be stirred violently and the magnetic field lines twisted up, stretched, torn, and reconnected in a furious turbulent action.

Our Sun produces X-rays in its outer atmosphere, the million degree corona which is visible as a faint pearly-white halo at times of total eclipse. The hot coronal gas is bound to the Sun by a cage of looping magnetic lines of force. It is believed that when these magnetic field lines are twisted into ropes by the action of sunspots, the energy stored in the magnetic field can be catastrophically released in the form of explosive X-ray flares that carry the power of billions of hydrogen bombs.

In VW Cephei, the Navy scientists believe that the mixmaster action twists up the magnetic fields between the two stars so that flaring action is continuous. The resulting X-ray emission is millions of times that expected from either star alone. So much power is available from the rotational kinetic energy that the flood of X-ray emission will not dim perceptibly for tens of millions of years.

VW Cephei belongs to a class of binary stars known as the W Ursae Majoris variables. In these pairs, the stars are so close that they often touch and eventually become joined. Optical astronomers find evidence for eclipsing variability with the period of the binary's orbit. Similarly, X-ray eclipsing is observed in VW Cephei. Huge quantities of energy and mass must flow across the stellar "bridge" in the turbulent contact zone. It is not known how the two stars have gotten into contact or what their ultimate fate will be. Does one star eventually swallow the other or does one of the pair collapse to a white dwarf and thus break contact with its companion?

The X-ray emission was discovered in the course of a complete sky survey by HEAO-1, launched in August 1977. The discovery has recently been confirmed by a pointed observation with the large X-ray telescope aboard the Einstein Observatory, HEAO-2. A search has been initiated of other W Ursae Majoris stars to detect similar X-ray emission. Thus far two more members of the class, 44i Bootes and YY Eridani, have been detected as X-ray sources. The X-ray emission is very likely characteristic of all members of this class of contact binaries.

Life Without Sun

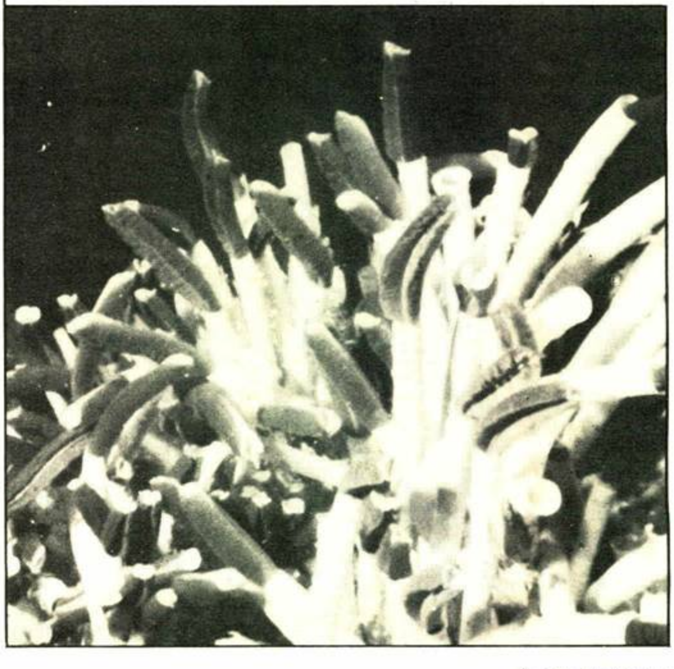
Mystery still surrounds several newly discovered oases of deep-sea animals that do not depend on sunlight for life. Their ability to derive energy from hydrogen sulfide issuing from volcanic fissures in the ocean floor earns these creatures the distinction of belonging to an entirely new kind of ecosystem, one with tremendous implications for theories of extraterrestrial life.

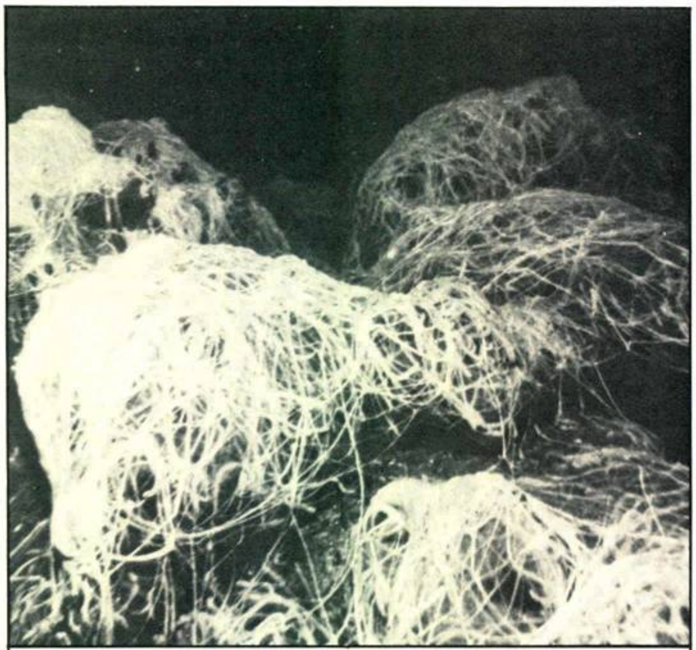
Scientists from the Woods Hole Oceanographic Institution are investigating the first examples of light-independent organisms originally discovered by geologists studying an undersea feature between the Galapagos Islands and Equador called the Galapagos Rift, part of a 40,000 mile Pacific Mid-Oceanic Ridge System created at the juncture of several of Earth's continent-sized crustal plates. Where these pieces of the Earth's crust meet underwater, molten magma emerges from the cracks, heating the 2° C seawater as high as 13° C (55° F) and releasing hydrogen sulfide (H_2S), the toxic chemical which gives rotten eggs their unpleasant odor.

In this strange nether world where sunlight does not penetrate and the remains of surface life sinking to the sea floor provide insufficient nutrients to support life, over 200 strains of bacteria (called thio bacilli) metabolize hydrogen sulfide, carbon dioxide, and oxygen to form the bottom rung of a food chain which supports larger species. Because the microbes utilize the chemical energy locked into hydrogen sulfide by the extreme temperatures of the Earth's crust instead of energy from sunlight, the process is called chemosynthesis, as distinct from photosynthesis, the energy source of green plants.

After the Woods Hole discoveries in the Galapagos Rift, a combined French-American-Mexican expedition found a separate oasis of similar chemosynthetic life 1,850 miles away in the East Pacific Rise off the Mexican coast. Among the animals found in chemosynthetic ecosystems along the Mid-Oceanic Ridge are huge, blood-red clams, blind crabs, dandelionlike creatures moored by threads, and sheathed tube-worms which grow up to 12 feet in length.

Scientists found huge "gardens" of tube worms in the Galapagos Rift hot vents. Photo by John Donnelly, Woods Hole Oceanographic Institution.





Mats of organisms nicknamed "spaghetti" (tentatively identified as enteropneusts or acorn worms) thrive in a world without sunlight. Photo by Jim Childress, University of California—Santa Barbara.

The importance of these discoveries derives in part from the sheer bulk of animal life capable of surviving without sunlight. The concentration of suspended organic matter at the volcanic vents is 300 to 500 times greater than at the adjacent sea floor and four times greater than in productive surface waters. Diving 2.5 kilometers to the undersea colonies in the minisub Alvin, Woods Hole marine biologists found a veritable jungle of life at a site they dubbed the "rose garden" because of the abundance of red-tipped tube-worms living there. Because of the tremendous pressure of 250 atmospheres, bringing undamaged specimens to the surface was difficult since organisms tended to disintegrate very quickly at sea level. It seems clear that the life forms are adaptations of surface species although animals such as the giant tube-worms are related so distantly to known forms that taxonomists are not sure in which phylum to classify them.

One of the most baffling questions is how these animals colonized the Galapagos Rift and sites 1,850 miles away since no environment intermediate between sunlight dependent and hydrogen sulfide supported zones has yet been found. While chemosynthetic bacteria are not unique to the newly discovered vents, they have previously always been found coexisting with photosynthetic life in a secondary role. The finds after the investigation of 40 miles of the Mid-Oceanic Ridge are impressive, yet they may represent only a small portion of the total volume and variety of life still to be found along the rest of the 40,000 mile rift system, the largest feature on Earth's surface.

Not only has the impact of the Mid-Oceanic Ridge discoveries been significant for marine biology, it has also made scientists consider the possibility of using hydrogen sulfide, a common waste chemical and one of the pollutants responsible for "acid rain," as the basis for chemosynthetic food production. Moreover, the existence of sun-independent ecosystems has implications for the possibility for extraterrestrial life. As far as the Mid-Oceanic Ridge creatures are concerned, the Sun as a source of food and heat might as well not exist. It may be that chemosynthetic life could originate and flourish in areas of the solar system where the lack of significant solar radiation has given exobiologists reason to rule out the possibility of life. Even where sunlight is scarce, geological activity may be capable of producing the necessary heat and chemical compounds to generate and sustain life.

In the June 1, 1979 issue of *Science*, scientists from the Voyager 1 imaging team reported that the gas venting from volcanos on Jupiter's moon Io "may consist predominantly of sulfur and sulfur compounds (such as H_2S and SO_2)." Although Io apparently lacks other precursors of biological activity, such as water or ice of any kind, it does join the Earth and Mars as a third definite example of vulcanism in the solar system. The seeming abundance of geothermal energy and its by-products combined with the possibility of chemosynthetic life could modify our view of the outer solar system as a barren wasteland and extend the search for extraterrestrial life into previously forsaken regions. Given sufficient time and a suitable environment rich in hydrogen sulfide or similar energetic compounds, life arising in subsurface caverns or on a planetary body with an atmosphere too dense to admit sunlight (such as seems to be the case with Titan, Saturn's largest satellite) might evolve to levels rivaling those on a sunlit world. While it is far too early to make definite predictions concerning the existence of extraterrestrial life in our solar system, the Mid-Oceanic Ridge discoveries indicate that hasty conclusions about the limits of life should also be avoided.

Galatheid crabs and mussels congregate in the warmth of a hot vent in the Galapagos Rift. The entire ecology of this deepsea "oasis" functions in total darkness. Photo by Robert Hessler, Scripps Institution of Oceanography. (All photos courtesy of the Woods Hole Oceanographic Institution.)

AstroNews

Primordial Matter

Astronomers from Caltech and the University College London have reported detecting the first pristine material in outer space left over from the beginning of the universe. The diffuse clouds of hydrogen they have found far outside our own galaxy will enable "unprecedented insights" into the processes that occurred after the explosion of the primeval fireball in the Big Bang that began the universe, the astronomers said.

The clouds' existence also allows a sort of "cosmic weather report" of conditions in space between the galaxies, according to the researchers, indicating that the intergalactic medium is cooler and more tenuous than was previously thought.

The scientists, who published their findings in the January issue of the *Astrophysical Journal Supplement Series*, are Caltech Professor of Astronomy Wallace L.W. Sargent and Assistant Professor of Astronomy Peter J. Young, and University College London Professor of Physics Alec Boksenberg and astronomer David Tytler. Their work was supported by the National Science Foundation.

The astronomers detected the intergalactic clouds by analyzing alterations in the spectrum of light from distant quasars, which were produced as the light passed through the clouds on its way to Earth. Quasars are ideal beacons for such studies because they are the most distant and the brightest objects in the universe, outshining entire galaxies of hundreds of billions of stars. The hydrogen in the intervening clouds, however, absorbs this light at certain wavelengths, producing spectral features called "Lyman-alpha" lines, which the scientists used as benchmarks to locate the clouds.

The observations of the quasars were made using two telescopes — the *200-inch* Hale telescope at Palomar Mountain in California, and the Anglo-Australian telescope near New South Wales. The astronomers were able to gather enough light to perform the spectral analyses by using an Image Photon Counting System developed by Professor Boksenberg with funds from the U.K. Science Research Council. The device contains a special intensifying television camera that amplifies the extremely faint images from a telescope more than ten million times.

While other astronomers have noted the existence of intervening clouds between the quasars and Earth, it was previously thought that the clouds were ejected from the quasars, rather than floating independently in intergalactic space. However, the new observations clearly establish that the clouds were indeed cosmologically distributed throughout the universe, the scientists said.

The astronomers have proposed that the clouds are pristine material from the Big Bang because they produce only hydrogen absorption lines, and none from carbon. Such carbon lines would show that the clouds had been "polluted" by material formed after the Big Bang, in the nuclear furnaces of stars. All nuclear substances with atomic weights heavier than hydrogen, helium, deuterium, or lithium were formed after the Big Bang by thermonuclear fusion processes in stars.

According to the currently accepted theory, as soon as the universe had cooled sufficiently for the first hydrogen nuclei to form, a certain number of them immediately fused into helium nuclei, with a tiny fraction of lithium nuclei also being formed. But the temperature fell too fast for any atoms heavier than lithium (such as carbon) to have been created out of the primordial matter.

The scientists were able to deduce that the intergalactic medium was relatively cool (about 300,000° Kelvin) and tenuous because higher temperatures and densities would have caused the clouds to evaporate within 100,000 years of their formation, long before the 10 billion or more years since the universe began.

Astronomers have long theorized that temperatures were extremely high between the galaxies because they needed some mechanism to explain why hydrogen atoms in intergalactic space appeared to be almost totally ionized, with their electrons stripped away. Quasars would only have been visible through a medium of ionized hydrogen, for neutral or un-ionized hydrogen would have easily absorbed all light from the distant quasars.

Therefore the findings by the four astronomers greatly aid another theory of hydrogen ionization — that there existed huge numbers of quasars whose powerful emissions ionized the hydrogen in the intergalactic medium.

The scientists plan further studies of the clouds, using both earthbound telescopes and the 12-ton Space Telescope to be orbited in 1983.

Flamsteed's Supernova?

Cassiopeia A (Cas A) is one of the strongest radio sources in the sky. It is believed to be the remnant of a titanic stellar explosion — a supernova — in which a dying star becomes so bright that it is a more powerful energy source than the entire Milky Way Galaxy, more than 100 billion times as powerful as the Sun. Analysis of this radio source and some faint clouds of gas associated with it shows that the supernova explosion should have occurred late in the 17th century. But no record of such an observation has been previously found, leading some theorists recently to propose that the supernova which gave rise to Cas A immediately collapsed into a black hole, preventing any light from escaping (see "More Black Holes?" in AstroNews, September 1979).

Now, however, William B. Ashworth, an historian of astronomy at the University of Missouri (Kansas City), claims that this explosion was in fact observed by the English astronomer John Flamsteed in 1680. Dr. Ashworth, announcing this discovery at the 155th meeting of the American Astronomical Society in San Francisco, pointed out that the original edition of Flamsteed's famous star catalog includes a faint star which he labelled "3 Cassiopeiae." No such star was ever observed again, and astronomers publishing subsequent editions of the catalog deleted this entry, believing it to be a mistaken observation. This star, however, is located in the same spot as Cas A.

Flamsteed's exact position for the star he saw and recorded is only 3 minutes of arc (one-tenth the diameter of the full moon) from the center of the supernova remnant. No visible supernova explosions have occurred in the Milky Way Galaxy since this one. Ashworth's discovery, if verified by subsequent analysis, will help contemporary astrophysicists better understand supernova explosions, the spectacular death throes of massive stars.

Information on Black Holes

Because of the enormous public interest in black holes, the Astronomical Society of the Pacific, an international nonprofit organization whose aim is to increase public understanding of astronomy, has recorded a two-minute taped message about these intriguing cosmic objects. Anyone interested in hearing the brief explanation can call the "astronomy hot-line" at (415) 661-0500.

For those wishing more information about the science behind the science fiction, a black holes information packet can be obtained from the Society. The packet contains a non-technical introduction to the various kinds of black holes and a bibliography for further reading. It also includes information on bumper stickers and T-shirts with the slogan "Black Holes Are Out of Sight" which can be ordered through the Astronomical Society of the Pacific. (Proceeds from the sale of these items help support the Society's nonprofit educational activities.)

To obtain a black holes packet, send your name and address together with $1.00 for postage and handling to:

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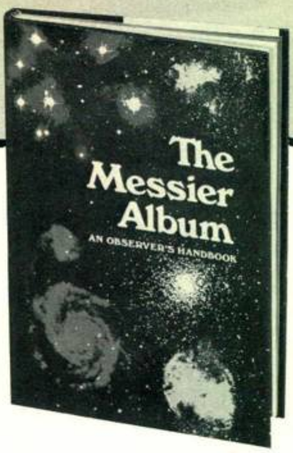
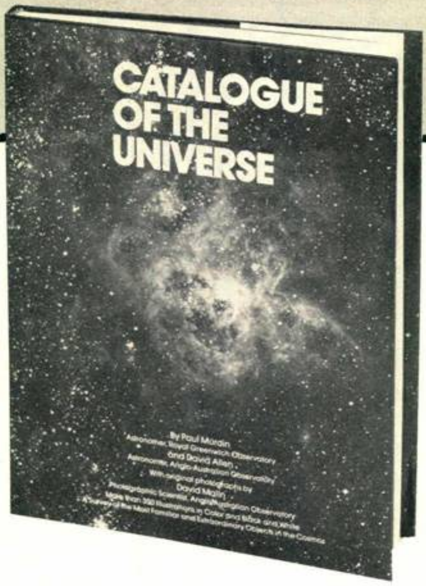


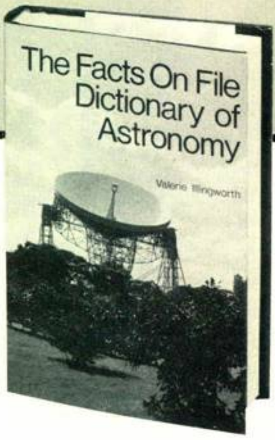
The Messier Album
John H. Mallas & Evered Kreimer

Two southwestern astronomy lovers teamed up to produce a fine observer's guide to the Messier catalog, Mallas supplying the visual sketches and description and Kreimer the photographs. The result is a splendid tour! Whether you own a telescope or not, you'll enjoy browsing through this deservedly popular assortment of nebulae, clusters, and galaxies. As an added treat, there's also a biographical sketch of Messier and a facsimile of his complete catalog. Hardcover, $12.50.



Catalogue of the Universe
Paul Murdin & David Allen

Encyclopedic in its coverage, the *Catalogue of the Universe* describes some 220 astronomical objects — each representative of its type. The sweep begins with clusters of galaxies and ends with the Earth as an astronomical object. An added feature are many photographs taken on the Anglo-Australian telescope by David Malin (some seen recently here in ASTRONOMY!). Hardcover, $17.00.



The Dictionary of Astronomy
Valerie Illingworth

How often have you wanted to know what an astronomical term meant — but didn't know where to look? Or wondered what some abbreviation stood for? If so, we've got just the source you've been looking for! Covering the range of astronomy from observing to astrophysics, the entries range from simple definitions to mini-essays. Hardcover, $18.00.

ASTRONOMY bookshelf

U.S. Observatories: a directory and travel guide, *Kirby-Smith* Indispensable for the astronomical traveler; shows how and where to tour major observatories. Paper, $7.50.

Space Shots, *Hapgood* Large-format picture book of celestial objects. Paperback, $8.50.

The Crab Nebula, *Mitton* Tells all about what goes on in that gassy remnant of an exploded star. Hardcover, $15.50.

The Moon Book, *French* Summarizes the history of the Moon and what the Apollo missions told us about it. Paper, $5.50.

Concise Book of Astronomy, *Mitton & Mitton* Intended for any newcomer to the subject, this book is simply written and colorfully illustrated. Hardcover, $11.50.

Astronomy: the cosmic journey, *Hartmann* Profusely illustrated survey of astronomy without mathematics. Fully indexed with glossary. Hardcover, $18.75.

Star Finder Excellent observing aid. Shows what's up at any time during the year: find out when Betelgeuse sets or Cetus rises. Paper, $3.25.

Moon, Mars, and Venus, *Rukl & Klepesta* Pocket-size lunar atlas in 76 plates; also has topographic and albedo maps of Mars and a radar map of Venus. Hardcover, $4.50.

Burnham's Celestial Handbook, *Burnham* The great modern classic about deep-sky objects; arranged by constellation, it covers the whole sky in 3 volumes. Paper, $9.50 per volume.

Seasonal Star Charts Guide to the heavens with 8 star maps and accompanying lists of objects in each constellation; has Star Finder planisphere on cover. Plasticized paper, ring-bound to lie flat. $6.75.

Atlas of Mercury, *Moore & Cross* Fine maps and Mariner 10 photos of the little planet; also text with facts, historical and scientific, about it. Hardcover, $10.75.

Star Names: their lore and meaning, *Allen* The classic source for learning about star names, zodiac, constellations, and celestial folklore. Paper, $5.50.

Cambridge Encyclopaedia of Astronomy, *Mitton* Up-to-date survey of modern astronomy; fully indexed for easy access and thoroughly illustrated. Hardcover, $36.50.

Celestial Objects for Common Telescopes, *Webb* Volume 1 is about the solar system; volume 2 covers all else, constellation by constellation. Paper, $9.00 (set).

Constellations, *Rukl* Popular pocket-size guide to the constellations. Has color map on one page with a list of objects facing it. Hardcover, $4.50.

The Milky Way, *Bok & Bok* The absorbing saga of galactic discovery — within our own "island universe." Tells how the shape and size of the Milky Way was dimly recognized and brought into clear focus. Paper, $6.50.

New Concise Atlas of the Universe, *Moore* Large, "coffee-table" guide to the sky with almost 1000 photos, 400 in full color. Hardcover, $31.00.

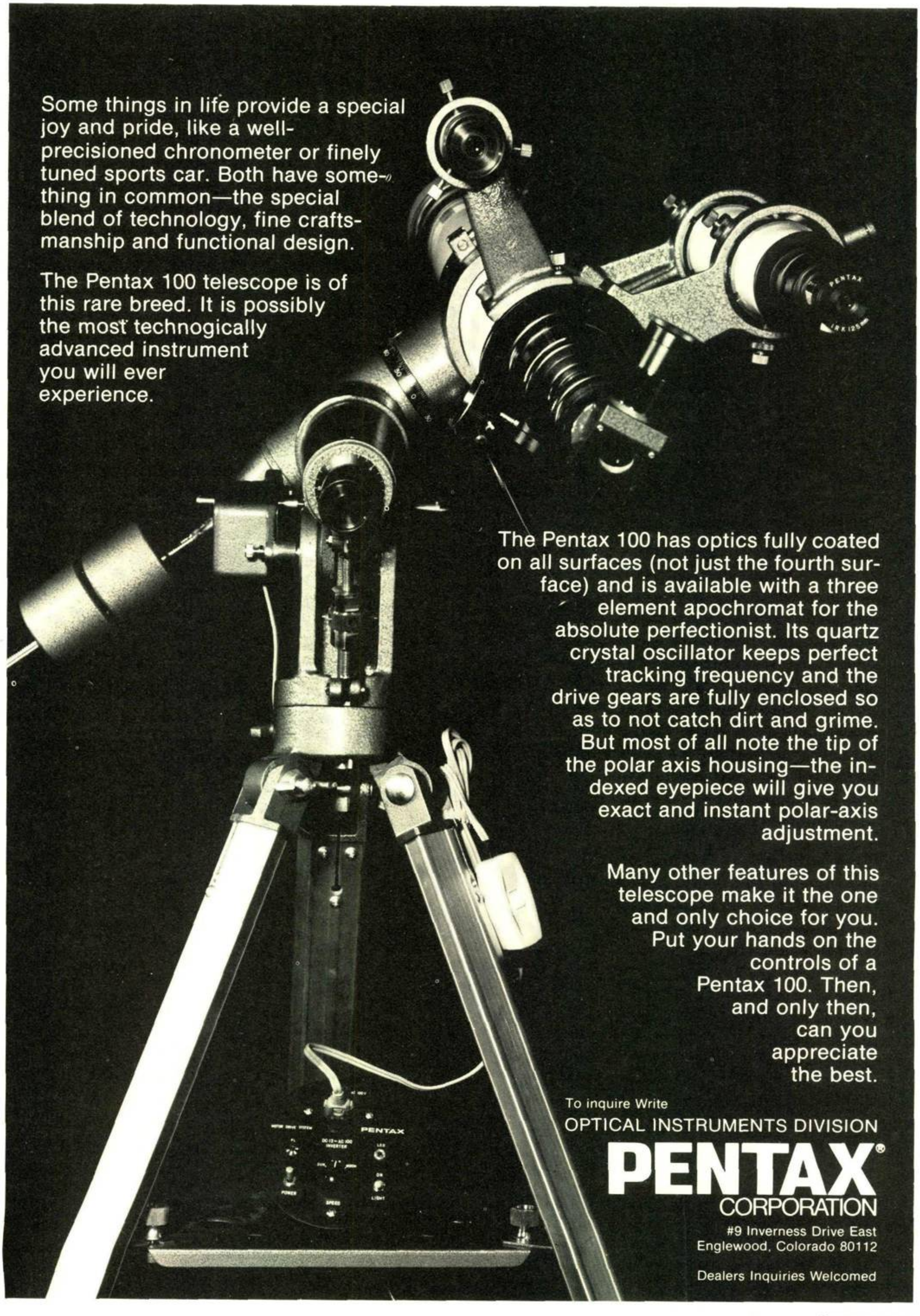
Deep Sky Objects, *Newton* Covers the standard Messier list as well as worthy NGC objects; has finder charts as well as photos. Hardcover, $12.50.

Astronomical Directory, *Gall* Lists addresses and phone numbers for astronomical societies, planetariums, and amateur astronomers all over the world. Paper, $7.25.

Astronomical Calendar 1980, *Ottewell* Takes you through the year, day by day, explaining all such astronomical events as occur. Paper, $8.50.

The Red Limit, *Ferris* Thrilling story of modern cosmology and its practitioners. Hardcover, $10.50.

Astronomical Companion, *Ottewell* Background information to supplement and enrich the Astronomical Calendar. Paper, $12.50.



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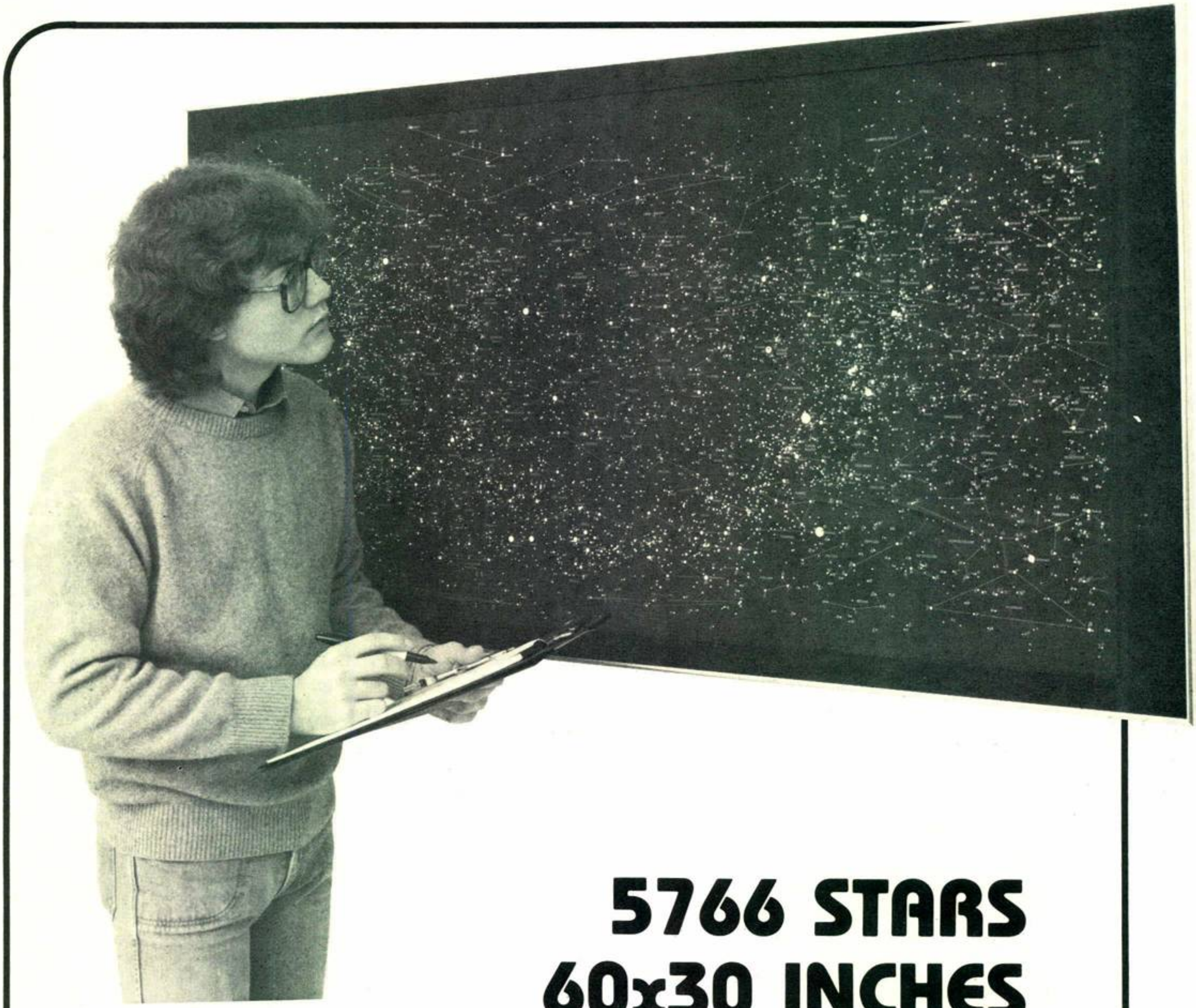

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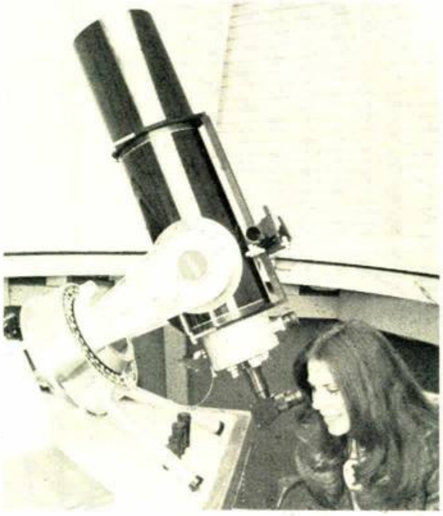

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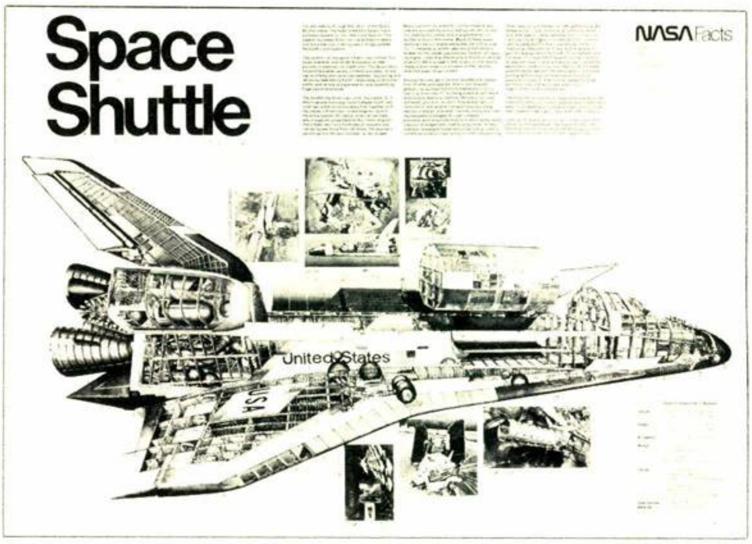


The Radio Universe 2

by
Clarence H. Annett

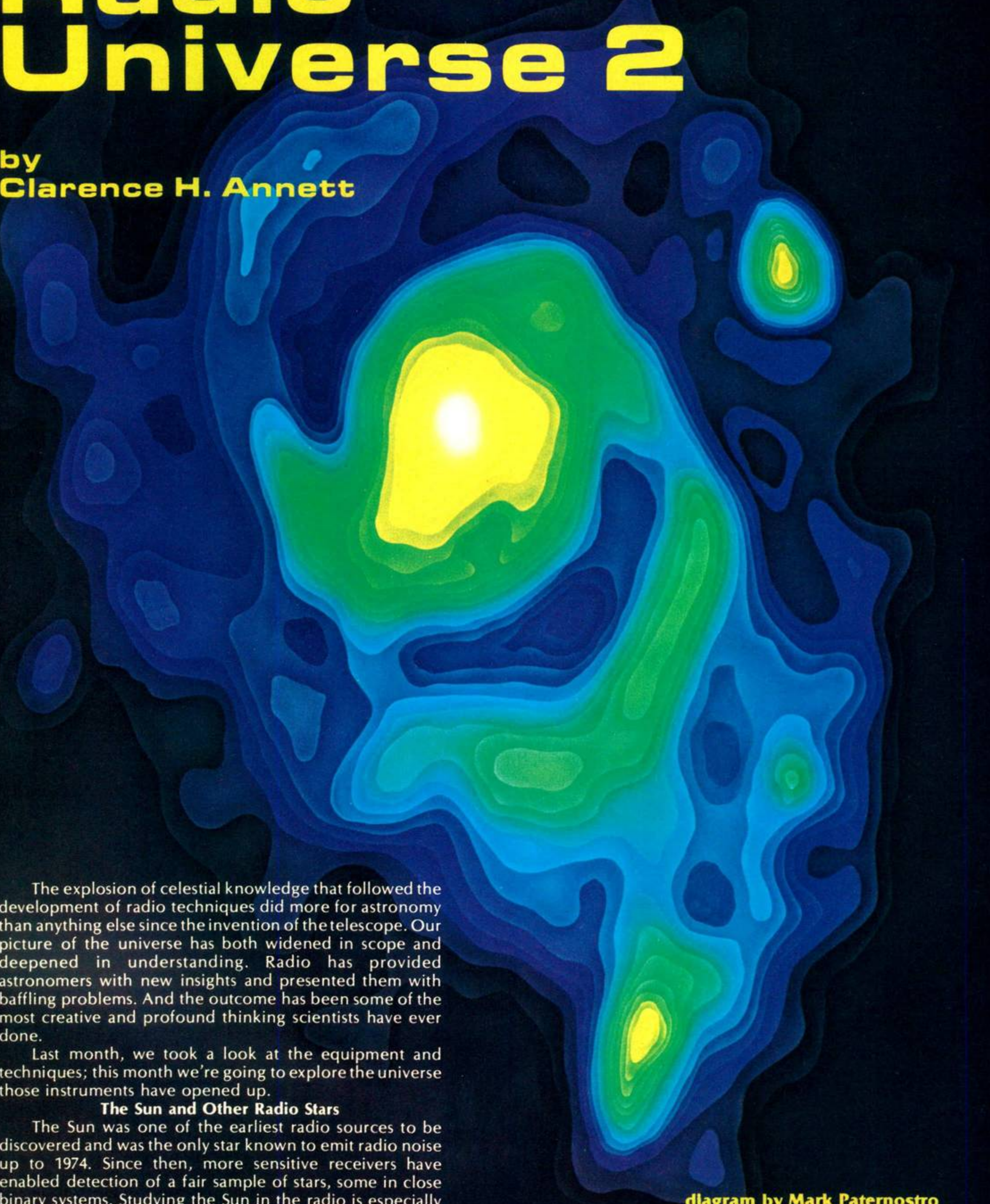


diagram by Mark Paternostro

The explosion of celestial knowledge that followed the development of radio techniques did more for astronomy than anything else since the invention of the telescope. Our picture of the universe has both widened in scope and deepened in understanding. Radio has provided astronomers with new insights and presented them with baffling problems. And the outcome has been some of the most creative and profound thinking scientists have ever done.

Last month, we took a look at the equipment and techniques; this month we're going to explore the universe those instruments have opened up.

The Sun and Other Radio Stars

The Sun was one of the earliest radio sources to be discovered and was the only star known to emit radio noise up to 1974. Since then, more sensitive receivers have enabled detection of a fair sample of stars, some in close binary systems. Studying the Sun in the radio is especially important since it is the only star we can examine in detail — and, of course, because our existence depends crucially on it.

The Sun is a complex radio source that mixes quiescent periods with several distinct types of outburst. Even during its quiet periods, the Sun gives off radio noise, but most of the energy comes during the major disturbances.

On a routine basis, the Sun displays two periodic radio disturbances — a slow rise to twice normal signal strength over three to four months, followed by a sharp drop, and a 27-day cycle which matches the Sun's rotation exactly.

The active Sun emits storms of "static" lasting from hours to days, in connection with sunspots and sporadic outbursts of fantastically high energy. These bursts can reach 10 million times the noise output of the quiet Sun and last for several minutes. They seem to originate in large and vigorous solar flares. The high frequency signals from these outbursts travel faster and reach the Earth before the low frequency ones do — a curious feature not yet wholly understood by astronomers.

Sunspot-related noise follows the 11-year sunspot cycle. The most active wavelength is about 10.7 centimeters, and the greatest outbursts from sunspots have a profound effect on the Earth — radio communication blackouts, aurorae, and variations in the Earth's magnetic field. A large outburst from the Sun may go as high as 10 billion Janskys in intensity (remember that we can detect about 250 millionths of a Jansky).

The problem scientists face with the Sun (and this applies to optical workers as well) is that astronomers are "data-rich"; while there are plenty of reliable observations, relatively few theories help them explain or suggest causes. In time, no doubt, the balance will swing, but for now — largely because of the extreme complexity of solar activity — many scientists are somewhat at a loss to account for its behavior.

Planets

Planetary geophysicists are absorbed in working out how the lumps of debris left over from the solar nebula take shape as planets and develop. They need to know all about a planet: its surface temperature, heat flow, structure of its atmosphere (if any), and so on. By looking at a planet in the radio, astronomers get information unobtainable in the optical region of the spectrum — information to help them construct theoretical models.

Most of the radio energy from a planet is thermal radiation from warm surfaces or atmospheres. Only Jupiter shows clear indications of nonthermal radio emanations. The exact cause of these radiations is not yet clear: at long wavelengths, bursts of jovian "decametric" radiation coincide with the revolution of Io, the innermost moon. The interaction of Io and the jovian magnetosphere produces some very odd effects — ones that the Voyager probes have done a lot to explain. At shorter wavelengths, the "decametric" radiation noise is constant.

The Interstellar Medium

Much of the space radiation bathing the Earth from all directions originates in the interstellar medium and radio is virtually the only way to observe it. Cold hydrogen gas — the bulk of interstellar material — radiates primarily in the radio region of the spectrum at 21 centimeters wavelength. Prior to radio astronomy, very little was known about this important part of the galaxy's material.

While neutral hydrogen can't be seen in the optical region of the spectrum, astronomers reasoned, it must be common — for we see indirect evidence for it many places. Theoreticians had predicted as early as the 1940s that it should generate a radio signal, but until detected in the early 1950s, no one knew how much of it might exist. Astronomers now know it's all-pervasive: about half the mass of the universe appears to be neutral hydrogen! By studying how it is distributed throughout our Galaxy, astronomers have now constructed many maps showing the Milky Way's spiral structure.

A second source of interstellar noise is the radiation which comes from charged particles moving at near-light speeds as they swirl in a magnetic field. Called "synchrotron" radiation because it was first seen in atomic particle accelerators, this radiation is very useful. Why? It shows where electrons and moderately strong magnetic fields exist. Synchrotron radiation is also polarized and by measuring the amount, astronomers can get an idea how strong the magnetic fields are as well as studying the energies of the electrons, both important clues to astrophysical processes.

Yet another source of background radiation is the 3° Kelvin blackbody radiation left over from the formation of the universe by the "Big Bang." Discovered in the microwave region (and earning the 1979 Nobel prize in physics for its discoverers), the shape of the signal's spectrum has important implications in cosmology (see "The Cooling Fire of Creation," ASTRONOMY, March 1980).

Finally, and perhaps most excitingly, radiation from interstellar space has betrayed the existence of many relatively complex molecules including water, carbon monoxide, formaldehyde, ammonia, ethyl alcohol, and about 30 others. One of the most complex molecules yet discovered is cyanoacetylene. Even cosmic masers have been found emitting intense, polarized, coherent radiation from a source with a very small angular diameter.

The complex molecules identified exist in "free" space as well as in nebulae with clouds of gas and dust. Until recently, most interstellar molecules were observed only in our own Galaxy; now some have been definitely identified in other galaxies. That the researchers keep finding increasingly more complex molecules has direct bearing on theories of the Galaxy's formation and the beginnings of life.

The Galactic Center

Earth receives radiation from both the galactic disk and the galactic halo, but by far the brightest radio source in the Galaxy is the center of the Milky Way. Radio emanations from there suggest several types of sources, for there's considerable variety in the signals. Some of it is synchrotron radiation from the strong magnetic fields of the galactic center, while other components are due to hot interstellar matter.

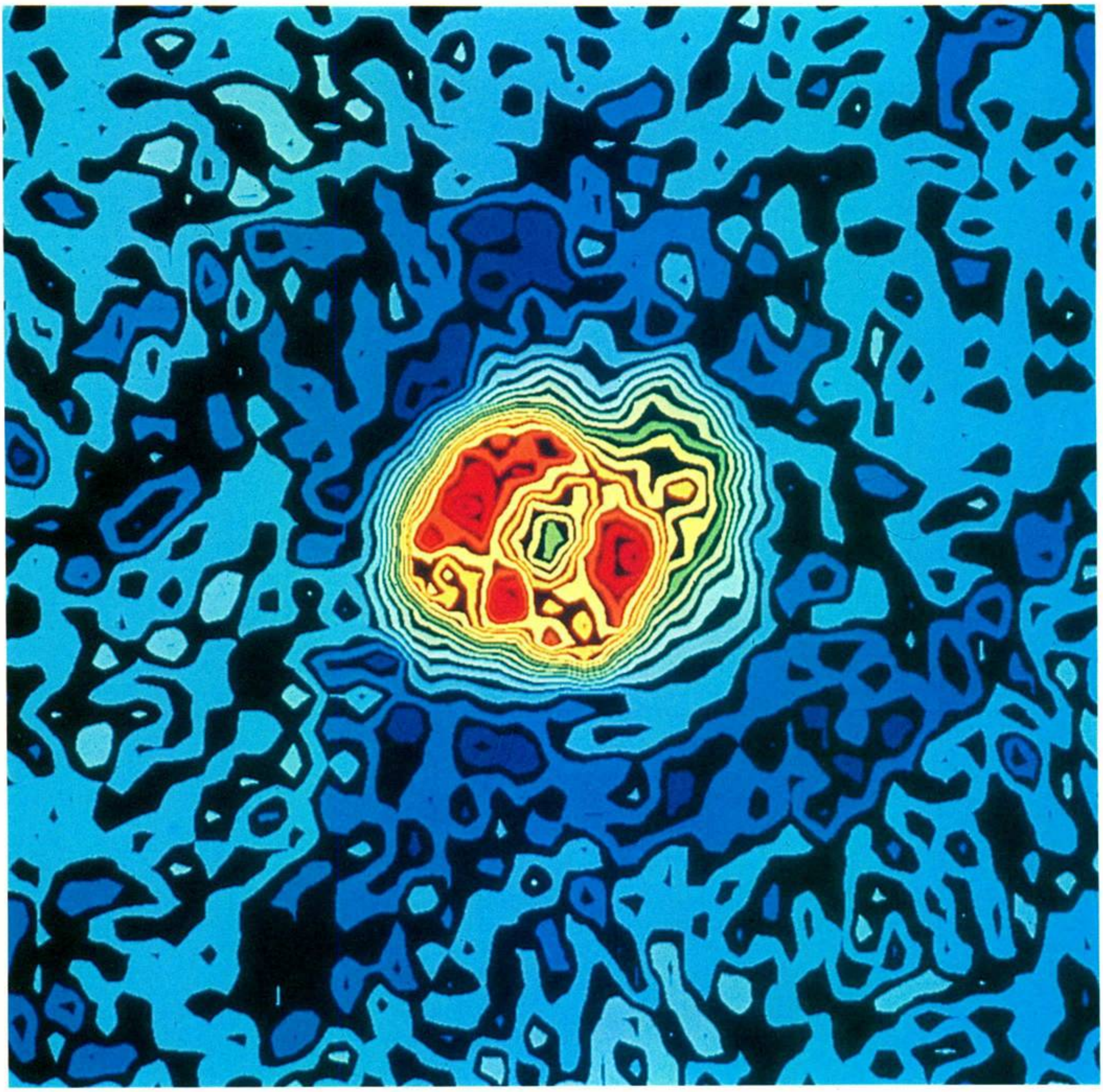
In the region of the galactic disk, radiation is also strong, showing that a magnetic field pervades the *entire* Galaxy. By listening to the frequency changes (Doppler shifts) in the signals from moving clumps of matter in different parts of the Galaxy, astronomers can pick up clues about the way our Galaxy rotates. These determinations are very difficult to make and research must continue if astronomers are someday to unravel the story of how galaxies evolve to look the way they do. At present, observations indicate that the Milky Way Galaxy rotates about once every 250 million years.

Supernova Remnants and Nebulae

Most stars evolve quietly, with no fanfare or fuss, emitting little or no radio noise. The Sun is one of these and only our proximity allows us to observe and analyze its emissions.

But the course of life isn't so smooth for a few: the massive stars undergo violent evolutionary events. They become novae or supernovae and are intense radio sources. In fact, many novae are brighter at radio frequencies than in the visual.

Unfortunately for astronomers, no supernova has happened nearby since the invention of the telescope some 400 years ago. Nevertheless, theoreticians expect that when one eventually does occur (as it will), it'll be a strong radio source, giving us a glimpse into the fiery conditions



NGC-6543, a planetary nebula informally known as the Cat's Eye Nebula, displays an involved structure when seen through radio eyes. Lick Observatory photograph.

surrounding a massive star when it blows up.

Interestingly enough, the gassy *remnants* of supernovae are also powerful radio sources. The best example is the Crab Nebula, the remnant of a supernova that was seen to detonate in 1054 AD. The Crab was the first radio source astronomers could link to a visible object, and is one of the strongest radio sources in the sky. It shows intense synchrotron radiation, indicating the presence of strong magnetic fields.

Other supernova remnants show strong nonthermal radio emission. The bright radio source Cassiopeia A is associated with optically visible, turbulent, high-speed shreds of nebulous material. The same is true for the Cygnus Loop, a huge, expanding shell of gas which gives off strong synchrotron radiation. In fact, many radio astronomers think that virtually all nonthermal radio sources in the Galaxy are supernova remnants.

There are exceptions, though: Some gas clouds are radio emitters but cannot be linked to known supernovae. These seem to be regions where new stars are forming. Radio astronomers observe atoms in these clouds at a much more active level than optical methods do; this has contributed to their understanding of the energies and processes involved in star formation.

Pulsars

Pulsars are radio sources that flash on and off with extreme regularity. Most don't have an optical counterpart, but those which do are all associated with supernova remnants. Pulsars were discovered accidently by Anthony Hewish, a radio astronomer at Cambridge University (England) in 1967. The first pulsar, CP 1919, was in the constellation Vulpecula. About 300 are known today, all located in the Milky Way Galaxy.

Each has a pulsation period between 0.03 and 3 seconds, and their flashes are regular to one part in a trillion or so. They are slowing down at a steady rate, but abruptly change this rate every now and then.

When pulsars were first found, astronomers came up with a lot of explanations for them — and some were really weird — but each explanation developed problems as more became known. Radio observations eventually led astronomers to calculate that pulsars should have a density hundreds of thousands of times greater than that of a white dwarf star: about 100 billion times that of water. Finally, the neutron star — a curiosity that came out of theoretical predictions in the 1930s and the only object which fits the mass requirement — was dusted off and moved into the realm of physical possibility.

At present, all the strong pulsars have been found and a lot of weaker ones. It's not likely that a great many more will be picked up until new advances are made in instruments — either more sensitive detectors (and we've about reached the limit here) or larger antennas in shielded locations.

Galaxies — Normal and Radio

All galaxies emit at radio frequencies, but most are not very active. The exceptions (called "radio galaxies") are very powerful sources of radio noise.

A radio galaxy is typically a very large elliptical galaxy, visually bright, which shows unusual visual features. A common example is M-87, which has a double nucleus and a luminous jet. Seyfert galaxies, a type having active nuclei, are also in this class.

When astronomers use the great resolution of a radio interferometer to examine a radio galaxy, they can pick out many small details of structure such as radio-emitting gas clouds, and this has uncovered some unusual features:

Radio galaxies appear to be undergoing some type of catastrophic event similar to a vast explosion, thought by relatively adventurous astronomers to be powered by gigantic black holes (see "Are Black Holes Really There?", ASTRONOMY, October 1978). Consider, for instance, the radio source Cygnus A. Cyg A is the most intense extragalactic radio source in the sky, and lies at the fantastic distance of 220 million parsecs or about 700 million light-years. This is too far away for detailed visual observation. Astronomers calculate that Cygnus A has a radio luminosity of *ten million times* our own Galaxy.

Most of this radiation seems to come from two gas clouds located on the opposite sides of the Cygnus A core source. Originally, astronomers thought it was two galaxies in collision. Now they think they're seeing two tremendous jets of gas broadcasting radio energy as they plow through the thin intergalactic medium. But so much remains to be learned that it's impossible to say for sure.

Quasars

Quasars, short for quasi-stellar objects (QSOs), were discovered by radio astronomers in early 1960. They are (apparently) very distant objects putting out far more energy than a galaxy but having an angular diameter about the size of a solar system, and in some cases smaller still. They appear to be the most distant objects known.

Late in 1960, Caltech astronomer Allan Sandage was able to indentify a 16th magnitude visual object corresponding to the quasar 3C 48. The object was a quasar.

Quasars have several features in common: All have larger red shifts than any other known objects, indicating fantastic recession speeds — up to an appreciable fraction of the speed of light. The optical ones resemble bluish stars. Some are "radio-quiet," but most have strong radio signals and shine brightly in the ultraviolet. Their spectra contain broad emission lines. Quasars vary in both visual and radio output over time in an irregular way. (See "Are Blazars Quasars?", ASTRONOMY, February 1980.)

Some quasars behave like Seyfert galaxies in their optical and radio signals, but seem to be much smaller physically. A quasar's angular diameter can only be measured using radio astronomy — it is far too small for optical methods. Astronomers can find out about this in two ways. The first uses a two-antenna interferometer technique over an intercontinental baseline (see "Using Earth as a Radio Telescope," ASTRONOMY, October 1979). This method gives an upper limit on angular diameter (in most cases) of 0.1 second of arc or less. The second way is to observe the occultation of a quasar by the Moon — a method which has lowered the upper limit to 0.02 second of arc.

Nobody really knows very much about what makes up a quasar. Precision work using radio interferometers has resolved a few into two or three distinct components, but this only complicates the picture. The fundamental problem is accounting for how these compact sources can emit such prodigious quantities of energy.

Some astronomers (and science-fiction authors) have rather daringly proposed that one or more quasars may exist in the center of our Galaxy, but for now this remains little more than conjecture (see "Do We Live in an Exploding Galaxy?", ASTRONOMY, December 1978).

Even less is known about the radio-quiet quasars. The scientists working on these problems hope that increases in instrumental power, such as completion of the Very Large Array (VLA) interferometer near Socorro, New Mexico, will provide more data for theorists to deal with.

Radio Cosmology

Radio astronomers have recently become engaged in an ambitious program to test general relativity. In simple terms, this test takes the form of a "law" which says the number of radio sources discovered should increase as the three-halves power of the threshold flux detectable on the Earth. Basically, this says that as we increase the sensitivity of our instruments, we should see more and more objects — and that the number of them found should increase at a certain rate.

When they postulate this, astronomers are assuming that all radio galaxies are equally luminous, that there is a constant density of radio sources in the universe, and, lastly, that the geometry of space is Euclidian.

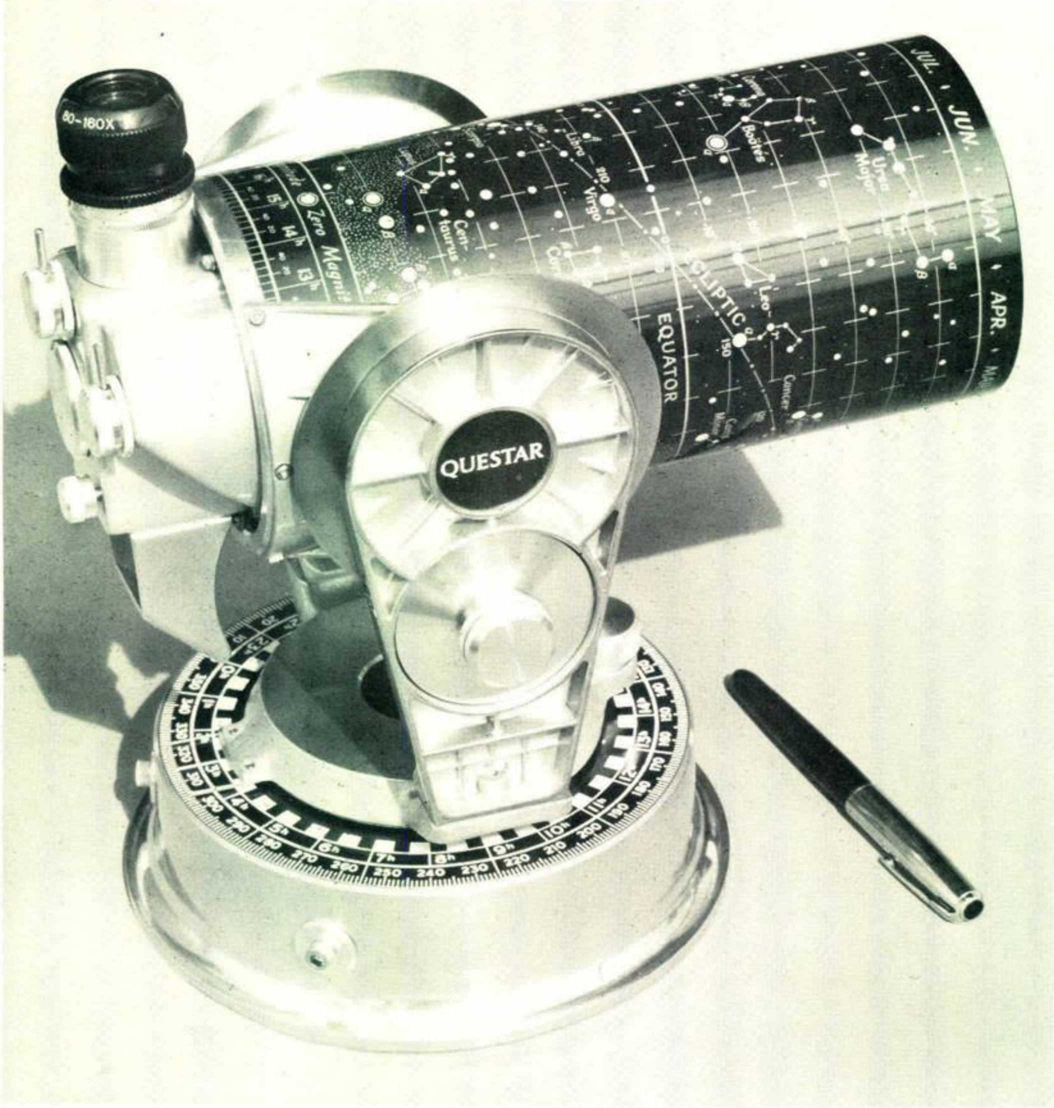
The first two assumptions can be independently verified by other methods, but the third assumption contains the crux: If the law holds true, that is, if the radio sources found *do* increase according to this rate, then space is Euclidian and not curved as relativity calls for. There is no other way to test this assumption except by proving or disproving the "law." Whichever way it goes, this clearly has very far-reaching implications for our ideas on the formation and history of the universe and our concepts of space, time, and reality.

Depending on how tests of the law turn out, general relativity will either have a sounder basis than ever before, or it'll be seriously weakened. This could well be the one most important result of radio astronomy in the future.

* * *

This brief survey has really only begun to touch on some of the most exciting facets of radio astronomical research today. If the past is any guide, we should expect that the universe currently unfolding in front of us is only going to get more and more interesting in the years to come. Non-optical astronomy (and this also includes spectral regions other than radio) has become the fastest-growing and most productive area of the field. Radio research being done today will answer many important astrophysical questions.

Thousands of galactic and extragalactic radio sources have been found, but they are only a small fraction of the total number of visually-identified objects. Although radio sources are not the biggest part of the universe, they are certainly among the most interesting. And if it seems, bewilderingly, that each answer immediately poses at least two more questions, reflect a moment and remember that a journey to a known place is seldom as much fun as a fresh exploration.



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WANTED — Camera lens (telephoto or standard) to fit an Olympus OM-1 camera. Must be optically suitable for astrophotography. Cost must be around $100.00. Contact Steve Corsi, 14629 Cortina Dr., La Mirada, CA 90638.

WANTED — September 1978, March 1978, March 1976, September 1975 issues of Scientific American; December 17, 1976, October 1, 1976, August 27, 1976 issues of Science. Must be in excellent condition. Write Aldo Erdic, 302 Windsor St., Thunder Bay, Ontario, CANADA P7B 1V8.

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ANNOUNCEMENTS — 26th National American Radio Relay League Convention will be held in Seattle, Washington, July 25-27, 1980. Theme is "World Friendship Through Amateur Radio" and includes world-wide speakers, seminars, manufacturer's exhibits. For registration and information write: 1980 AARL National Convention Committee, P.O. Box 68534, Seattle, WA 98168.

ANNOUNCEMENT — Lockport Astronomy Association meets September - June; 3rd Tuesday, 8 p.m. at Lockport Senior High. May - October, Wednesday evenings, weather permitting, public night observing free. For information contact Sylvia Mosure, Secretary, 3165 Roland Dr., Newfane, NY 14108. Phone (716) 778-8662.

ANNOUNCEMENT — Societies in North Carolina are forming the Carolina Astronomy Network and will hold STAR-BOUND '80 in May or September. Any individual or society who wants to join the Network or attend the convention should contact: C.R. Andrews Jr., 3131 3rd St. Dr. NW, Hickory, NC 28601.

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ANNOUNCEMENT — Middle East Regional Convention of The Astronomical League, June 20, 21, 22, 1980. Brandywine College, Rt. 202, Wilmington, Delaware. Includes paper sessions, swap shop, astrophoto exhibit/contest, astro-art, star party, observatory tour, business meeting, banquet with Dr. Harry Shipman speaking. Contact Denny Horazak, 2007 Oak Lane Rd., Wilmington, DE 19803.

ANNOUNCEMENT — The 1980 SERAL Convention will be held in Orlando, Florida on June 19-21, 1980. For information write Central Florida Astronomical Society, 810 E. Rollins, Orlando, FL 32803.

ANNOUNCEMENT — The Catawba Valley Astronomy Club meets 2nd Thursday at 7:30 p.m., Lenior-Rhyne College in Hickory; Caldwell Community College in Hudson; or Maiden High School in Maiden. You are invited. For information contact Greg Kirby, 12 East St., Granite Falls, NC 28630.

ANNOUNCEMENT — Attention: Matthew Harrington. Please write; I lost your address (sorry). Anthony Ceraso, 403 New Broadway, Brooklawn, NJ 08030.

ANNOUNCEMENT — The National Deep Sky Observers Society 1980 National Convention will be held at the Ambler Pennsylvania campus of Temple University in suburban Philadelphia on August 15-17. For registration, accommodations or activities information write: Convention Chairman, Ed Kaczanowicz, 434 E. Rockland St., Philadelphia, PA 19120.

ANNOUNCEMENT — Santa Cruz County's Society for Astronomy and Space Flight meets on the 1st Saturday of each month, 7:30 p.m., in the Cabrillo College Planetarium. Films, telescope viewing and lectures. No dues. Call (408) 688-6466 or 425-6331.

ANNOUNCEMENT — Northeast Regional Convention of the Astronomical League, June 20-22, Yale University, New Haven, CT. Dr. William Van Altena, Yale Astronomy Department, will speak on "The Space Telescope in the 1980's." Astronomical tours, special events. Contact Pat Tierney, 18 Countryside Cir., Northford, CT 06472. Phone (203) 484-0623.

ANNOUNCEMENT — Interested in reviving the Westchester Astronomical Society or forming a new astronomy club in Westchester County, NY. Contact A.L. Ponjee, 200D High Point Dr., Hartsdale, NY 10530. Phone (914) 761-6061.

ANNOUNCEMENT — Telescope Users Clinic: To assist telescope owners solve problems concerning balance, alignment, focus, drive and optics. Instruction also on telescope use, alignment with Polaris, setting circles and astrophotography. Date: May 17, 1980 at Rio Hondo College, 3600 Workman Mill Rd., Whittier, CA. For information contact Western Observatorium, Inc. Phone (213) 698-0468.

ANNOUNCEMENT — Call Seattle (206) 324-ASTR.

ANNOUNCEMENT — Willamette Valley Astronomers — Eugene Astronomical Society meets the 4th Friday of each month at EWEB. Come hear programs, attend star parties and meet fellow amateurs. For more information call (503) 484-2676.

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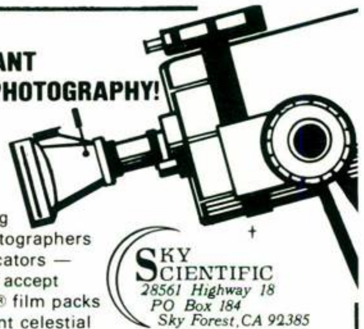

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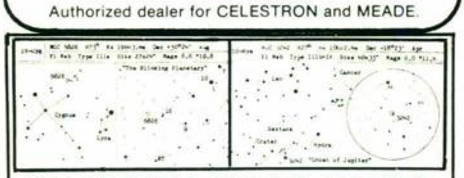

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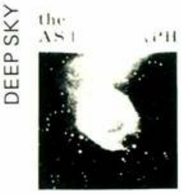

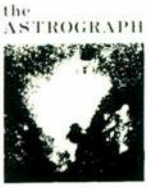

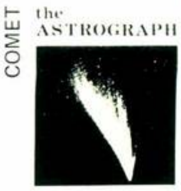

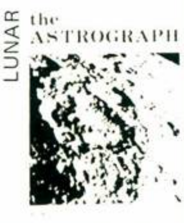

ASTRONOMY REVIEWS

Using the Telescope: a handbook for astronomers
J. Hedley Robinson
112 pages, hardcover, $9.95
John Wiley and Sons (1978)

Using The Telescope promises to be a guide for those who wish to put their telescopes and observing equipment to uses other than random stargazing. Aimed primarily at the beginner, the book covers basic techniques in practical observational astronomy. Much of the material however has been available to the observer for many years, and while instrumentation and most every object worthy of observation is discussed, this presentation really does not deliver enough to live up to its own promise.

The author begins with a discussion of selection, characteristics, and maintenance of telescopes and their related accessories. He continues by outlining adjustments to the equatorial mounting and basic techniques in astronomical photography. After time and position are covered, the author plunges into brief descriptions of observational programs for the major bodies of the solar system along with binary and variable stars. Star clusters, nebulae and galaxies are briefly mentioned at the end. The book includes a brief glossary, appendices, bibliography and index.

However, it proves to be a disappointment from the very first chapter. Beginning with a brief overview of instrumentation, the author attempts to introduce the reader to some of the basic equipment required to undertake observing programs described in later chapters.

Unfortunately, the chapter is flawed with errors of omission. Although reflectors and refractors are superfically described and compared, virtually nothing is said about their relative merits in differing observing programs. The author makes no mention of the various kinds of reflectors and completely ignores today's popular catadioptric designs.

Similarly a satisfactory description of eyepieces is marred by the omission of any discussion of the Barlow lens. The rest of the chapter is affected in much the same way, giving the impression that its inclusion in the book was an afterthought. Fortunately the book improves somewhat from this point, but not to the degree one would hope for.

Following a better than average overview of time, clocks, and coordinates, the book gives brief but adequate descriptions of practical observing programs for the solar system and deep-sky objects. Of particular interest is the chapter dealing with observation of the Moon. Here the author describes a program by which transient lunar phenomena (TLPs) can be detected through repeated observations with color filters. This program along with sections on lunar occultations, variable stars and sun spots seems to offer material that can truly guide the amateur astronomer toward making valuable contributions to knowledge.

The other sections, while not quite as valuable in terms of practical results, can provide the reader with some interesting projects that go beyond simple stargazing. It's a shame, however, that the author devoted so little space to photographic search for novae and supernovae. This is an area where the amateur can contribute substantially with relatively modest equipment. Robinson's one sentence covering this area of work can only be considered a major oversight.

Using The Telescope also leaves much to be desired in its editing style. Much of the text is cumbersome, and in a few cases can only be described as inane. The reader finds for example on page 9 that one advantage of the reflector is "good light grasp in larger sizes." Although this seems to be self-evident for telescopes in general, it's interesting to note that refractors are not assigned similar characteristics. On page 58 in a discussion on daylight observation of Mercury, the author tells us that "it will be noted that the mention of offsetting from the Sun presumes the observation is to be made in daylight." Is this some sort of British humor?

Examples of sloppy editing are also evident. In the brief glossary, which despite its title is still grossly inadequate, you find "the Great Andromeda Nebula" given as an example of a galaxy, while on the very same page the author states that "...owing to possible confusion, this practice [of calling a galaxy a nebula] is dying out." Admittedly these examples are not truly representative of the text as a whole; however, the writing is most definitely in need of improvement.

J. Hedley Robinson has not lived up to the standards that he set for himself in his previous work. While his new book includes a scattering of reasonably satisfactory observing hints in addition to some excellent renderings of the planets by P.B. Doherty, the work falls short of its stated purpose. Much of the coverage is awkward while some very important material is omitted altogether. Amateur astronomers interested in a guide to practical observational astronomy will do better to seek it elsewhere. *Robert Provin.*

Light
Richard Morris
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Bobbs-Merrill Co. (1979)

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Light, in its many manifestations, is the medium of astronomy. And *Light* explores this phenomenon of photons from a remarkable number of angles. From the Greek philosopher Empedocles' first theory (that light is emitted by the eye, strikes the object, and bounces back) to today's modern quantum theory, the question "What is light?" has engaged the minds of philosophers, artists, and scientists for millennia.

Morris is very thorough in his examination. He even explores the mytho-religious implications. Our common assumption of "light" as "good" and "darkness" as "evil" springs from the ancient tenets of Zoroastrianism. This is where our identification of God as "the Lord of Light" and the devil as "the Prince of Darkness" comes from.

Morris spends a lot of time looking at the fascinating Zoroastrian beliefs. And he moves smoothly from there right up to the present movie "myth" of *Star Wars*. Why do you suppose Luke Skywalker is clothed in white, and Darth Vader (a truly dark-sounding name) in black?

The author also looks at light from the artistic point of view, describing the evolution of *chiaroscuro* (the modeling of forms using light and shadow) in the Renaissance; William Blake's remarkable use of light; and the theories and practices of the Impressionists.

The development of photography led to new uses for light, new questions, and new answers. Morris doesn't neglect this, and certainly it's importance: astronomy entered a new era with the development of the photographic plate.

Astronomy buffs shouldn't be put off by these viewpoints; light is just as much their tool as it is of theologians and painters. But skywatchers will surely concentrate on Morris' chapters that deal more specifically with their field. "Theories of Light" is a fine look at the work and achievements of Archimedes, Galileo, Newton, Maxwell, and Roemer. It was their efforts which led to the modern concept of the quantum theory. This theory was first formulated in 1900 by Max Planck, who postulated that light was made of discrete bundles of particles. But Planck himself could never accept the implications of his own theory; to the end of his life this great physicist tried to undo his own work, but in vain. Einstein's epochal 1905 paper on the photoelectric effect proved that light had both wave and particle characteristics at the same time (a discovery for which he won the Nobel Prize). Morris also outlines the later contributions of Thomson, Rutherford, and Bohr to our understanding of light.

The quantum theory also explains the workings of "Lasers," another chapter in *Light*. Morris notes that in the beginning, lasers were a tool with no use — a situation that's radically changed in the years since its invention. Now lasers are used for everything from cutting clothes patterns to welding detached retinas to measuring the distance from Earth to the Moon.

Beginning in the early 1960s, the military researched the possible military uses of the laser. Could it become a "death ray"? Morris himself, it seems, worked briefly on such a project, but he professes to know little of what he was working on. A graduate student at the time, Morris says he was low man on the totem pole, with no "need to know."

But Morris, with a Ph.D. in physics, knows a lot more about the "light from the creation" and black holes. He explains, with simplicity and eloquence, the implications of the 3° Kelvin universal background radiation found by Arno Penzias and Robert Wilson — who themselves just received Nobel Prizes for their discovery. That all-encompassing radiation is the light from the creation itself, the Big Bang.

Black holes are objects so massive that nothing, not even light itself, can escape. It is only appropriate that Morris ends his book with a look at objects that could spell the end of the universe — and of light. As the poet Francis Bourdillon wrote: "Yet the light of the bright world dies, / With the dying sun." *Joel Davis.*

Planets and Moons
William J. Kaufmann, III
219 pages, hardcover, $13.00; paper, $7.50
W. H. Freeman (1979)

The second of Kaufmann's proposed trilogy covering modern astronomy, *Planets and Moons*, is the companion to *Stars and Nebulas* (reviewed in the September 1979 issue). Following a chapter on the origin of the solar system, the author devotes a chapter to each of the planets out to Jupiter, and then deals with Saturn and the outer planets, and the various minor bodies of the system in the final two chapters. The text is low-key and aimed at the non-mathematically inclined reader. Many of the recent spacecraft photos are used for illustrations; 8 are in color.

The Rocket Team
Frederick I. Ordway III and Mitchell R Sharp
462 pages, hardcover, $14.95
Thos. Crowell (1979)

The subtitle says it all: "...how a small group of engineers changed world history." Ordway and Sharp trace the story of the development of the liquid-fueled rocket from the early experiments during the 1920s to the Saturn V moon rocket. The emphasis quite properly is on the efforts of the German engineers led by von Braun. (Robert Goddard in the U.S. was also working on liquid-fueled rockets, but for a variety of reasons his work wasn't influential to the same degree.)

For those who revel in the minutiae of history, the story of the V-2's development is fascinating.

Origin of the Earth and Moon
A. E. Ringwood
295 pages, hardcover, $24.80
Springer-Verlag (1979)

One of the perennial questions any planetologist is likely to be asked is: Where did Earth and the Moon come from? And there are few questions for which it is harder to provide a detailed answer.

Ringwood, a professor of earth science at the Australian National University, has written a technical monograph at the advanced undergraduate level that stresses a geochemical approach to the question, in accordance with his belief that chemical interactions are "at least as important as those of gravitational and magnetic fields."

Einstein's Universe
Nigel Calder
154 pages, hardcover, $10.00
Viking Press (1979)

To celebrate the centennial of Einstein's birth, the BBC, PBS, and Nigel Calder put together a television program about Einstein and his theories. Starring Peter Ustinov as a latter-day Everyman, the show was broadcast in the U.S. over PBS. The book lacks Ustinov but makes up for it by going into Einstein's theories in more detail, thus providing a somewhat clearer exposition of relativity — although the book is still aimed at a popular level.

star dome

april: close-up on leo/leo minor/sextans

by Dewey Schwartzenburg & James Mullaney

Spring's long-awaited arrival is accompanied by a rebirth of interest in nature — not only in Earthly matters, but in celestial as well. With the chilly nights of March giving way to milder April evenings, observers are encouraged to spend more time outdoors under the clearing spring skies.

Why not pick some evening in April when the sky is clear and simply go out to look up at the night sky for an hour or two? Lie back in a comfortable lawn chair or on a blanket, relax and just watch the slowly wheeling heavens above. As your eyes become adjusted to the dark, you'll find you're seeing more and more stars. See how many constellations you can pick out—if you're already fairly familiar with the constellations, concentrate on the smaller, dimmer, less obvious groupings and see how many you can identify. If the stellar precincts are *terra incognita* to you, this is a good time to work on learning the main constellations of spring. Start from Ursa Major, the Big Dipper, which is nearly directly overhead at this time of year, and work your way down to the horizon.

The night sky is indeed a beautiful sight, especially on a clear moonless evening away from the light of the cities, perhaps after one of the showers April is famous for has washed dust from the air. On such a night, as we discussed here last October, you can expect to see about 2900 stars with the naked eye. That figure, of course, is based on the vision of the average person, so if you have particularly acute eyesight, you may be able to see a great many more. Binoculars, or even small opera glasses, will increase the number greatly. But can you imagine what it would be like if you could see stars down to the thirteenth magnitude with your naked eyes alone? What a sight the night sky would be then!

No human being can, of course, but the idea is not entirely ridiculous. The sensitivity of our eyes is entirely a function of our evolution as inhabitants of the Sun's third planet, 93 million miles from an average G2-type star. It could be that alien beings on other planets have evolved with entirely different visual sensitivities.

For example, the sensitivity of our human eyes peaks at about 5550 Angstroms and covers a range of wavelengths corresponding almost exactly to what we receive from the Sun (as filtered by Earth's atmosphere, of course). Therefore we might expect that the inhabitants of a planet circling a star significantly hotter than the Sun would have eyes whose sensitivity peaked in the ultraviolet range, just as the light of their sun would. (This of course neglects to take into account the possible shielding of the planet's atmosphere, which could result in a different range of wavelengths reaching the planet's surface than that actually emitted by the star.)

Other factors, of course, must also be considered. Human beings are basically diurnal, or daytime, animals, although we do have a certain degree of night vision. Nocturnal animals, however, have a significantly greater ability than humans to see at low light levels. The large-aperture eyes of such nocturnal animals as owls are obviously designed by evolution to gather as much light as possible. An interesting question would be the limiting magnitude a nocturnal animal could see — for example, how many of the Pleiades can an owl pick out?

Even more interesting, though, is the question of intelligent beings on other worlds, whose suns may shine brighter or dimmer than our own. Owls, of course, are more interested in spotting mice than in counting Pleiades. Might we not reasonably expect intelligent aliens to have evolved eyes enabling them to see as clearly on their worlds as we can on ours?

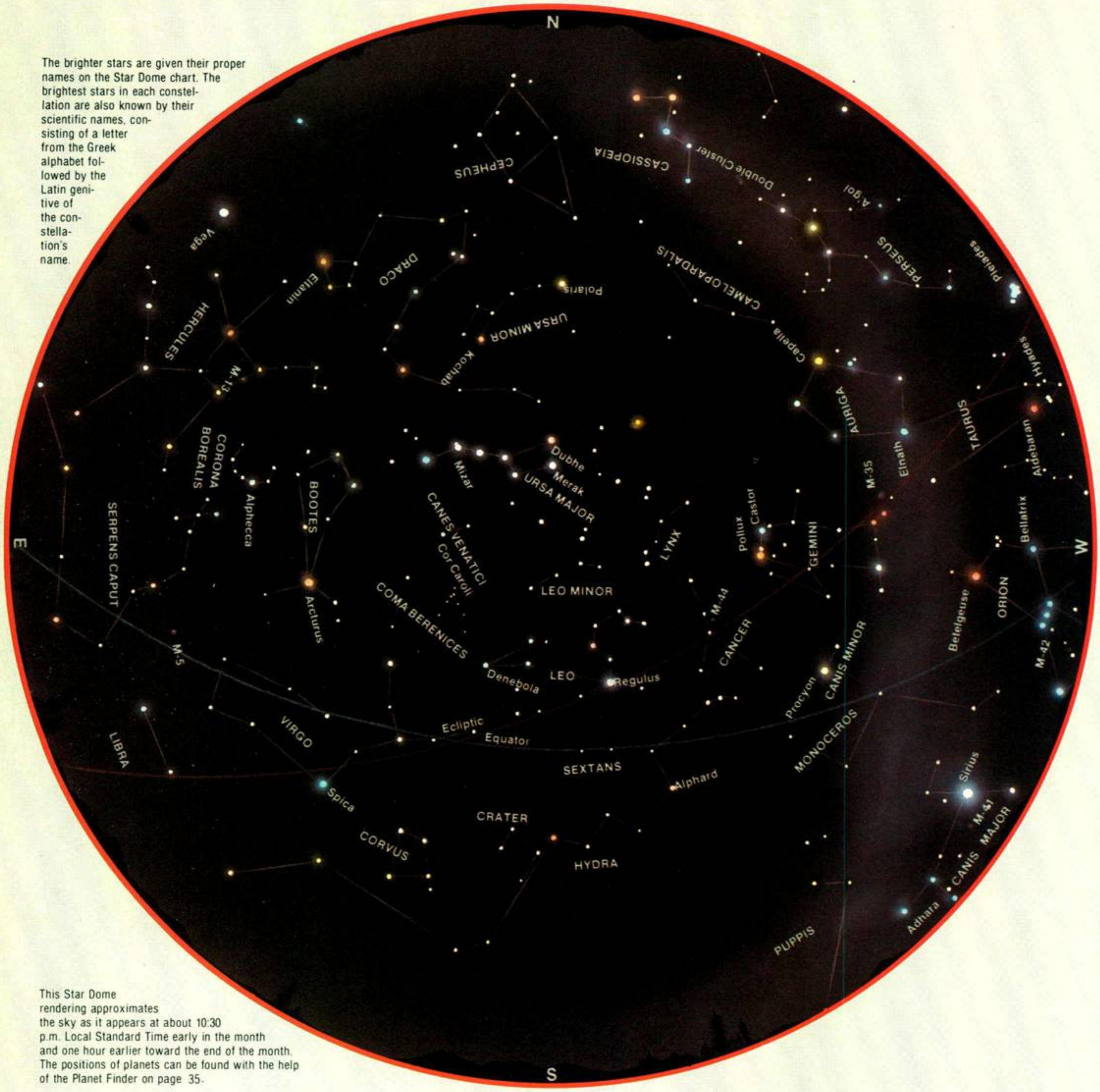
This question is not a new one. In fact, the French astronomer Camille Flammarion, writing around the beginning of this century, considered it in terms of the other planets in the solar system. Knowing the distances of the respective planets from the Sun makes it easy to calculate the relative light levels on each planet (neglecting such effects as clouds and possible atmospheric obscuration). Assuming that the magnitude limit for humans on Earth is 6.0, Flammarion went on to calculate what the magnitude limit would be for the inhabitants of each of the planets.

Obviously, the mercurians have the worst view of things. They could see stars only down to magnitude 3.9, which would leave the night sky a bleak-looking place indeed. The venusians (venereans?) do better, with a magnitude limit of 5.3. Even if there were venusians, of course, they would never see the stars at all until they managed to fly above their atmosphere's eternal clouds. Therefore we can imagine that their first sight of the night sky, even with a limiting magnitude of 5.3, would surely be quite overwhelming.

The martians would do quite well at counting Pleiades, for they could see down to magnitude 6.9. And because they are somewhat closer to Jupiter than we are, the sight of the four Galilean moons swinging back and forth in clear view would be one of the most dramatic sights in the martian night sky. We can feel sure that if there ever was an intelligent martian race, they must have all been Copernicans from the beginning with such a prominent model of the solar system right there in their sky!

Of course as we move farther out in the solar system this idea becomes more and more fanciful, both because of the inhospitality of the outer worlds to intelligent life as well as the fact that if there is life there of any sort, it must

The brighter stars are given their proper names on the Star Dome chart. The brightest stars in each constellation are also known by their scientific names, consisting of a letter from the Greek alphabet followed by the Latin genitive of the constellation's name.


N
CEPHEUS
CASSIOPEIA
Double Cluster
Algol
PERSEUS
Pleiades
Vega
Eltanin
DRACO
Polaris
CAMELOPARDALIS
HERCULES
URSA MINOR
Kochab
Capella
Hyades
M-13
AURIGA
TAURUS
CORONA BOREALIS
Dubhe
Merak
Mizar
URSA MAJOR
Elnath
M-35
Aldebaran
BOOTES
Alphecca
SERPENS CAPUT
E
CANES VENATICI
Cor Caroli
LYNX
Pollux
Castor
GEMINI
Bellatrix
W
ORION
Betelgeuse
LEO MINOR
M-44
Arcturus
COMA BERENICES
CANCER
M-42
M-5
CANIS MINOR
Procyon
Denebola
LEO
Regulus
Ecliptic
Equator
VIRGO
LIBRA
MONOCEROS
SEXTANS
Alphard
Sirius
Spica
CRATER
M-41
CANIS MAJOR
CORVUS
HYDRA
Adhara
PUPPIS
S

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month and one hour earlier toward the end of the month. The positions of planets can be found with the help of the Planet Finder on page 35.

be buried deep within heavily obscuring clouds. Still, it is interesting to know that hypothetical jovians could see stars down to magnitude 9.6, and the saturnians, in addition to the incredible sight of their rings in the night sky, would have a crowded sky including all stars brighter than the eleventh magnitude! (Come to think of it, though, having those beautiful rings up there might well be the equivalent of having several dozen full moons in your night sky every time you went out to observe....)

Finally, Uranus and Neptune offer the finest night skies of all. The uranians would have a visual magnitude limit of 12.4, and the neptunians, with an unaided view of the night sky down to magnitude 13.4, could easily see innumerable galaxies glimmering like tiny, fuzzy snowflakes against a crowded background of literally millions of stars. Imagine seeing the Virgo cluster with your naked eyes! We can imagine that of all the inhabitants of the solar system, the neptunians would be the most advanced in cosmology, having mapped the large-scale structure of the universe early in their history.

Flammarion, writing at the turn of the century, didn't know about Pluto, which was only discovered in 1930, so he didn't calculate a limiting magnitude for the plutonians. As it turns out, that's not so easy to do, since Pluto's highly eccentric orbit carries it from a point closer to the Sun than Neptune to truly interstellar space nearly twice as far out. Taking as an example the aphelion distance of Pluto, the limiting magnitude would be about 15, while the perihelion distance gives 13.3.

The aphelion value is very interesting. Being able to see all objects down to the fifteenth magnitude means that the plutonians would be able to see more in the sky with their naked eyes than we can with a 16-inch telescope. But what eyes they must have! The plutonians would be creatures with eyes whose pupils were 17-18 inches in

diameter, in order to gather that much light. Alternatively, alien eyes might be so designed as to "store up" incident photons, effectively giving the being a long-exposure look at things and so enabling it to see dimmer objects without an excessively large eye aperture. In this case we can imagine the creature gazing at the sky for an hour or so, gradually letting the image build up in its eyes rather like a developing instant photograph.

Of course it is hard to see how a planet as poorly illuminated and heated by its sun as Pluto or even Neptune could ever have evolved life at all, much less intelligent beings able to contemplate and appreciate the beauty of the night sky. But life may not after all be limited by the conditions we know limit us here on Earth, and we may well have surprises in store for us when we finally venture out far enough into this vast, beautiful cosmos we inhabit.

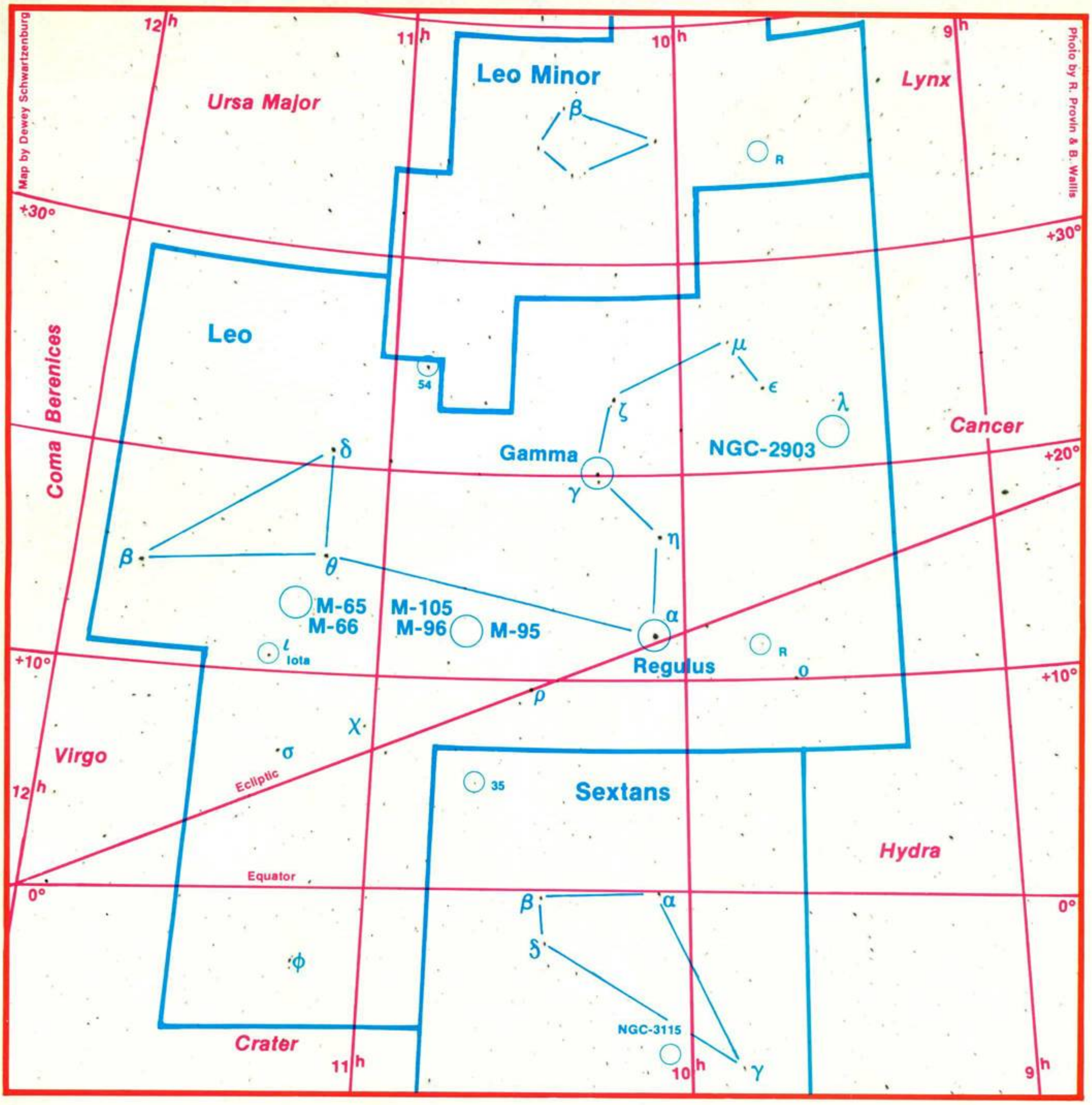
close-up

Leo/Leo Minor/ Sextans

Harbinger of the spring, the constellation Leo the lion, adjoined by Leo Minor and Sextans the sextant, is an impressive 12th order of size among the 88 constellations, and is heavily stocked with wonders (as our table of objects indicates).

Leo Minor ranks only 64th in sky area, and although it is peppered with faint galaxies and double stars, none are really outstanding enough to rate a place in our showpiece roster. Nevertheless, don't ignore Leo Minor. Telescope users who delight in explorations away from the "beaten track" will find this region an alluring adventure field on dark nights.

Sextans, one of the "modern" constellations, was named by Hevelius in the late 1600s to commemorate the instrument so important for stellar measurements. Even less prominent than Leo Minor to the north, Sextans has no stars brighter than fifth magnitude.



Map by Dewey Schwartzenburg

Photo by R. Provin & B. Wallis

Leo, however, is a splendid zodiacal constellation, with its recognizably leonine star pattern sprawled high across April's southern meridian. Lying directly in the path of the ecliptic is Leo's first magnitude luminary, Regulus — often occulted by the Moon.

This month's region is noted both for its stellar couples and its unique pairs of distant island universes. Leo's galaxies require a telescope for proper viewing, but some of its double stars are bright and wide enough to be seen in binoculars. One such pair is Zeta (ζ), found in the well-known "sickle" of Leo. Zeta is often confused by novices with the beautiful telescopic double Gamma (γ), which lies just below it. Zeta Leonis consists of fourth and sixth magnitude suns a roomy five minutes of arc apart. There is also a fainter star in the same field to the south.

Another neat binocular duo is Tau (τ) Leonis, situated beneath the lion's hindquarters. Locating it offers good practice in the technique known as "star hopping." Begin by setting on second magnitude Delta (δ), and then "walk" your way southward to Theta (θ), Iota (ι), Sigma (σ), and finally Tau. This fifth and seventh magnitude combo is separated by 90 seconds, and their tints have been described as lemon and pale blue.

To fully experience the lure and excitement of this region, telescopic scrutiny is necessary. This month's survey spans the range from nearby interstellar space to the mysterious depths of intergalactic darkness.

NGC-2903

Lying just 1½° due south of the fourth magnitude star Lambda (λ) Leonis is a little-known surprise of this month's region: the great spiral galaxy NGC-2903. Shining at magnitude 9.1, its fuzzy glow should be apparent in your finder as you look three lunar diameters south of Lambda.

NGC-2903 is a fairly tightly wound spiral with a number of arms, but these will not be distinguishable in small apertures. Instead, you will see a noticeably elongated glow measuring about 11′ by 5′, somewhat brighter toward the center. Photographs with large observatory telescopes have revealed an intricate pattern of eight bright knots in the nucleus of NGC-2903. These knots were originally thought to be huge regions of ionized hydrogen, but their true nature is still under debate.

NGC-2903 presents another mystery, this one historical. It seems that it was originally seen as double by the great observer Herschel. Since the *New General Catalog* was based on Herschel's work, this object appeared in that catalog with two identification numbers, NGC-2903 and NGC-2905. Few, however, see this spiral nebula as double now. Do you?

Regulus

The leader of Leo is 1.3 magnitude Regulus, marking the lion's heart at the bottom of the sickle's handle. (Some prefer to view this familiar figure as a reversed cosmic question mark hanging eternally over us in the sky.) This lovely star is visible for eight months out of the year, and is a warming sight when seen rising in the east at winter's end.

Barns called this object "a noble sun." It is a blue-white main sequence star of spectral type B7, lying 84 light-years from us — therefore being the nearest of Leo's showpieces. Smyth described its hue as "flushed white."

Regulus has an eighth magnitude companion 177 seconds northwest of it; both stars are drifting through space together. Olcott rated this a difficult object in a three-inch telescope even though it can be glimpsed in binoculars. Webb wrote that the small star "affords a beautiful contrast" with the primary, although he was referring to the magnitude difference rather than the colors.

The companion's color seems to have some strange, nondescript hue — usually given as white but with uncertainty. An intriguing comment about this object was made long ago by famed astronomy historian Agnes Clerke. She said this star's color was "seemingly steeped in indigo" — a curious remark which we should try to confirm for ourselves. What heavenly tint do you assign to the companion of Regulus?

Gamma (γ) Leonis

Nearly twice as far away as Regulus lies one of the finest binary systems anywhere in the sky. This is second magnitude Gamma (γ) Leonis, the bright star at the bend in the sickle. Also known as Algieba, this beautiful golden duo was discovered by Sir William Herschel in 1782.

Its 2.6 and 3.8 magnitude suns are in slow orbital motion about each other over an uncertain period of at least 600 years. As a result, both the position angle and separation are increasing ever so slightly from year to year. Their present values are 123° and 4.3 seconds. These figures are from measurements by Charles Worley (one of the few remaining visual observers of double stars in the world today).

Closest approach of the two stars (0.4 second) occurred in 1741, just prior to their discovery. Maximum separation of 4.6 seconds is predicted for the year 2063 A.D. The actual average space distance between them is 130 astronomical units or 17 light-hours (about twice the diameter of our solar system). This actual separation was calculated by the noted Belgian astronomer Jean Meeus. Information like this helps us more fully to appreciate what we are seeing at the eyepiece.

Gamma Leonis is a magnificent sight in even the smallest of telescopes — especially at high power in good seeing, as our drawing of the view through a three-inch refractor at 180x indicates. It is split nicely at 100x but its duplicity is evident with as little as 30x to an experienced eye.

Most observers see both the members of this pair as golden yellow in color. Other hues, however, have frequently been reported. Herschel called the stars white and reddish white, while Webb logged them during different years as gold-greenish red, yellow-greenish yellow, and yellow-deeper yellow. Barns gave a consistent orange and pale yellow. Pickering included Gamma in his famous roster under "White Double Stars," but added: "Both components yellow rather than white."

This pair's tints do seem to vary from night to night because of atmospheric effects. As is the case with most bright doubles, these hues are more definite in small telescopes than in large ones. A greenish cast to the companion can often be seen in two to four-inch telescopes, but both stars look the same in bigger instruments. Their actual spectral types are in fact rather close: K0 for the primary and G5 for the companion.

The great astronomer Otto Struve long ago called Gamma Leonis "one of the finest double stars in the northern sky" — and Struve had personally examined thousands of them. Olcott wrote: "It is best observed when it is not quite dark, or in moonlight." He gave the colors as yellow and green in his three-inch refractor.

About a half a degree south of Gamma is an interesting field star that bears watching. This is fifth magnitude 40 Leonis — an object suspected by some early observers as being a variable star, but never confirmed as such.

M-95, M-96, and M-105

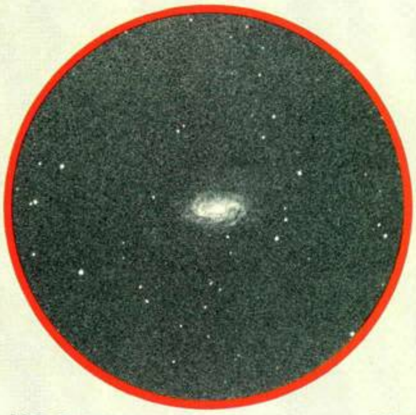
Behind Leo's starry framework lurks an unsuspected cosmic wilderness populated with remote galaxies awaiting your attention. Two of the best, M-95 and M-96, are a pair of spirals located in the lion's body. You can pick them up in your telescope by sweeping with a low-power eyepiece 9° east of Regulus on a dark transparent night.

Both appear round and are fairly large and bright for galaxies. M-95 shines at 10th magnitude and measures about six by four minutes of arc in extent. M-96 is a magnitude brighter and five by four minutes in

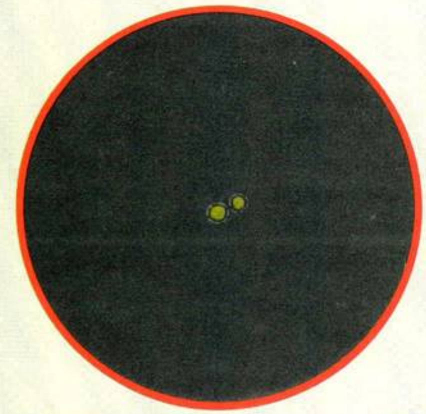
Selected Objects — Leo/Leo Minor/Sextans

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950) Dec.	
*NGC-2903(–5)	§S	9.1	11.0′x4.7′	09^{h}29^m	+21°44′
R LMi	m★	6.3-13.2	372^d	09^{h}43^m	+34°45′
R Leo	m★	4.4-10.3	313^d	09^{h}45^m	+11°40′
NGC-3115	§0	9.3	4.0′x1.2′	10^{h}03^m	–07°28′
*Alpha (α) Leo	★^{3}	1.4,7.9,13	177″,2.5″	10^{h}06^m	+12°13′
*Gamma (γ) Leo	★^{2}	2.6,3.8	4.5″	10^{h}17^m	+20°06′
35 Sex	★^{2}	6.3,7.4	6″	10^{h}41^m	+05°01′
*M-95	§ʃ	10.2	6.1′x3.9′	10^{h}41^m	+11°58′
*M-96	§S	9.1	5.0′x4.0′	10^{h}44^m	+12°05′
*M-105	§0	9.2	2.2′x2.0′	10^{h}45^m	+12°51′
54 Leo	★^{2}	4.5,6.3	6″	10^{h}53^m	+25°01′
*M-65	§S	9.3	7.8′x1.5′	11^{h}16^m	+13°23′
*M-66	§S	8.4	8.0′x2.5′	11^{h}18^m	+13°17′
Iota (ι) Leo	★^{2}	4.1,7.0	1″	11^{h}21^m	+10°48′

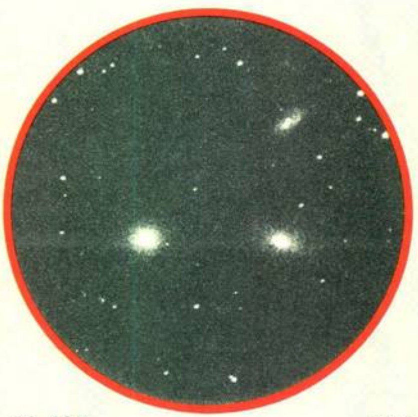
★	*Star*	m★	*Regular Variable*	●	*Globular Cluster*	§S	*Spiral Galaxy*
★+	*Bright Star*	n★	*Irregular Variable*	■	*Planetary Nebula*	§ʃ	*Barred Spiral Galaxy*
★^{2}	*Double Star*	ʜ★	*Eclipsing Variable*	□	*Bright Diffuse Nebula*	§#	*Peculiar Irregular Galaxy*
★^{3}	*Triple Star*	○	*Open Cluster*	§0	*Elliptical Galaxy*		



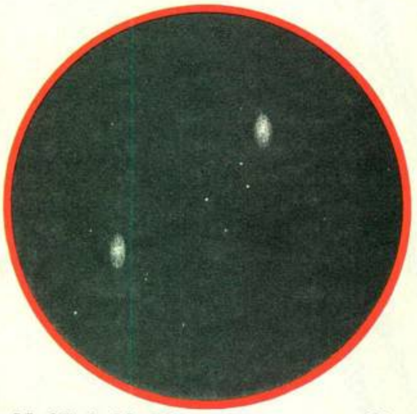
NGC-2903 **60x**



Gamma Leonis **180x**



M-105 **90x**



M-65 & M-66 **45x**

NGC-2903, a beautiful spiral galaxy, was seen as double by Herschel. The spiral structure will not be visible in small instruments. Photo by Thomas L. Dessert. Gamma Leonis, a pair of golden yellow stars, is separated by a tight 4.3 seconds of arc. The two stars shine at magnitudes of 2.6 and 3.8. Drawing by James Mullaney. The elliptical galaxy M-105 (on left) is accompanied by two fainter galaxies, NGC-3384 (right below) and NGC-3389 (right above). Photo by Jack Newton. M-65 (at lower left in this sketch) and M-66 are a bright pair of spiral galaxies, similar in size and magnitude, that lie a few degrees south of Theta Leonis. Drawing by James Mullaney.

size. Some observers feel these objects are more closely matched in brightness than these figures suggest.

You can see these galaxies in a three-inch telescope at 45x on a good night. They are easy objects in a six-inch reflector and beautiful sights in larger amateur instruments. A 1° eyepiece field just includes both of them, but some observers prefer to view them separately, each centered at the middle of the field. M-96 is the brighter and easier to see of the two; M-95 is found 1° to the east.

Webb called M-96 a "very bright nebula" but said nothing about M-95, only listing it. Barns described this galactic duo with his usual enthusiasm: "A nest of nebulae! Two fairly bright, with starry centers, others fainter but interesting, in a region scarce of bright stars...Worth many adventures." His observations were made with a home-built 10-inch reflector.

One of the neighboring objects mentioned by Barns is M-105, a small ninth magnitude elliptical system just two minutes of arc in diameter. It lies nearly a degree northeast of M-96 amid a clump of faint galaxies.

All three of the great stellar systems are at the same distance from the Milky Way Galaxy — nearly 30 million light-years. They appear to form a physical group gravitationally linked together — a kind of colossal, scaled-up version of a multiple star. The soft glow of their countless suns beckons the observer from across vast expanses of space and time.

M-65 and M-66

We end our survey of this month's far-flung region with another distant pair of galaxies. These are M-65 and M-66, considered by many as the best galaxies in Leo. They lie under the lion's hindquarters, midway between the stars Theta (θ) and Iota (ι), and are bright enough to be picked up in a good finder.

M-65 is listed as 9.3 magnitude, and M-66 as 8.4; both measure an elongated eight by two minutes of arc in extent. These spirals are brighter and much closer together than M-95 and M-96, lying about 20 minutes apart in roughly a north-south direction. Both fit nicely in a 1° field and are a captivating sight in four-inch and larger telescopes, as our drawing shows.

Olcott, strangely, did not mention either this pair of galaxies or M-95 and M-96. Barns described M-65 and M-66 as "very curious and mystifying. Worth diligent study." Webb went further: "Two rather faint objects, elongated visually in different directions, in a low-powered field, with several stars. M-66 rather the larger and brighter." Smyth thought M-65 appeared larger than M-66, and saw them elongated in the same direction. D'Arrest simply commented that M-66 was "magnifica."

Some modern observers see M-65 as brighter than M-66, although the reverse is actually true. In such a case, correct identification of these objects is especially important. Those using star diagonals on a refractor or a catadioptric telescope should note that north and south are erect but east and west are reversed (a mirror image). Thus their view will not match the orientation of our drawing or published field charts of this pair.

Despite such technicalities, these remote star cities are well worth scrutiny by the visual observer. Their spiral arms are tightly wound and not obvious, but there is still much to see and contemplate. M-66, for example, has an irregular "curdled" appearance, looking somewhat more like a diffuse nebula than a galaxy.

A number of other faint galaxies lie near M-65 and M-66, including NGC-3628, an edge-on spiral to the north of the pair. Another is NGC-3593, a spiral just over a degree west of them. Both of these objects shine at 11th magnitude and can be seen in four-inch and larger instruments.

Like its fainter and wider copy to the east, the M-65/M-66 system is probably physically associated, for both galaxies lie roughly at the same distance from us — also around 30 million light-years. It appears that each of the pairs we have examined are simply the brighter members of actual clusters, since they are surrounded by other galaxies. Instead of two pairs of island universes, we are actually dealing with a double cluster of galaxies within the same constellation.

Nature seemingly prefers to work in pairs and groups — whether it be atoms, stars, galaxies, or even people. The splendor of this month's region shouldn't be kept only to yourself. Invite a friend to join in on your next observing session so that he or she too can experience the thrill and excitement of astronomy. As an old English proverb states: "...a joy that's shared is a joy made double."

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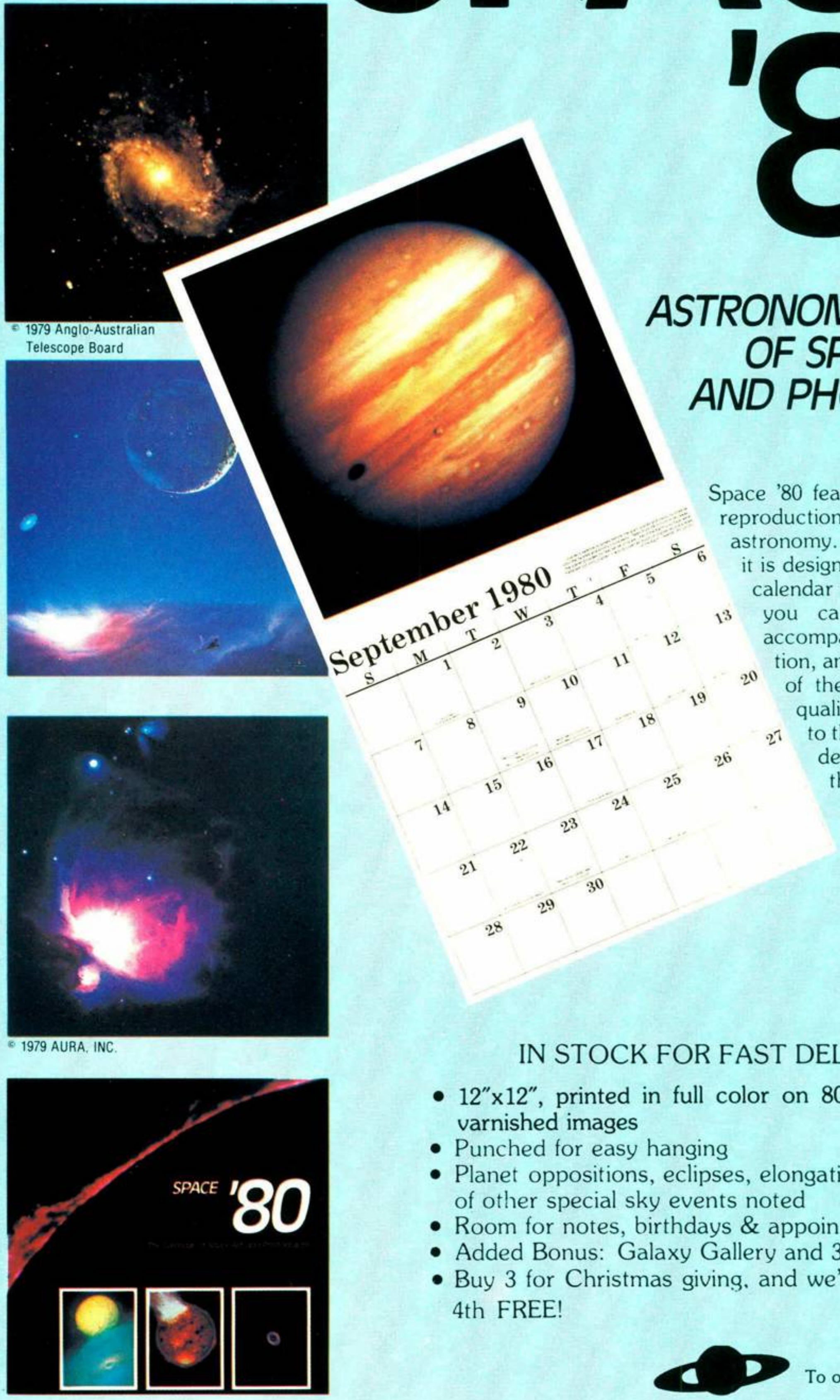

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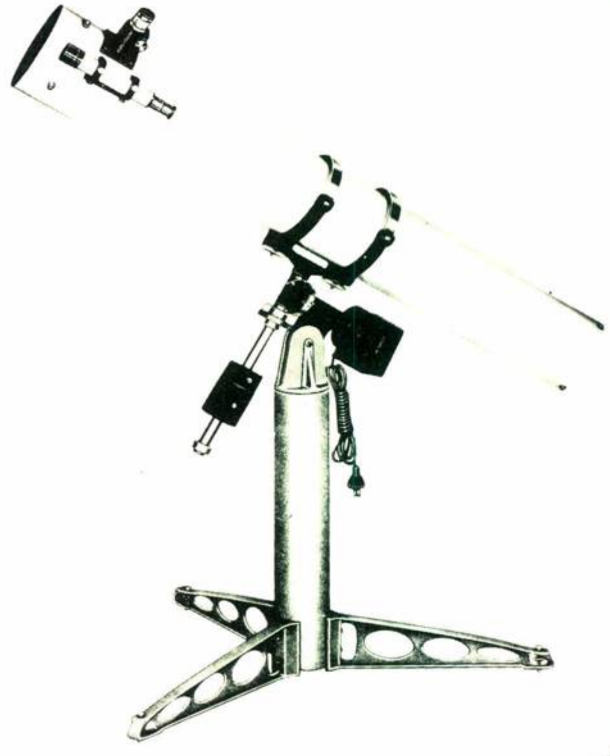

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